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The Schoolhouse—Its Heating and Ventilation

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CIRCULATION OF AIR—II

It has been the experience of the writer that when a well-adjusted combination of the plenum and exhaust systems is installed in a school building, more economical and satisfactory results are obtained than by the use of either system independently.

When the exhaust is a little in excess of the plenum, say about five per cent., the heat that is lost by leakage by the plenum method is utilized to warm the air drawn into the room through the outer walls, but in so many small places that uncomfortable drafts are not produced.

When the corridors, clothing and sanitary rooms are properly ventilated there is little danger of foul air reaching the class-rooms from such sources. This is at variance with the recommendations of many persons, but it is the experience of the writer in making many hundred tests of the heating and ventilation of schoolrooms.

LEAKAGE OF AIR AND HEAT

The subject of leakage of air and heat has not apparently received the attention from heating and ventilating engineers which it requires. In certain cheaply constructed buildings, where a very strong exhaust was in use, the writer has frequently found twice and sometimes three times as much air going out at the outlet as was coming in at the inlet. This is excessive, and should be guarded against by proper adjustment of dampers and heat in the exhaust flues.

In some of the mechanical systems of heating and ventilation in use in school buildings the velocity of the air at the inlets is too great and the size of the pipes or ducts is too small. Six feet velocity per second at the inlet is enough, and five feet per second, or three hundred feet per minute, is better, although in some cases, where air is brought into high-studded rooms over eight feet from the floor, a velocity of seven feet per second is not objectionable.

In arranging for an air supply for any system of heating and ventilation the number of cubic feet of air to be supplied per minute, divided by 300, will give the area in square feet for the pipe or flue.

Uncomfortable drafts will be caused if the air is brought into the room at too great a velocity, no matter whether by a gravity or a mechanical system.

Air may be forced through a main supply pipe at a velocity of 800 or 1,000 feet per minute by a fan, or at even a greater velocity by the expenditure of additional power, which, however, is not always true economy; but the risers or ducts leading to the rooms should be designed to admit the air into the room at not over 360 feet average velocity per minute.

Taking a small riser from the main duct and increasing the area at the entrance into the room will not give the best results.

There should be a steady and certain outflow of vitiated air through the extraction flues. It will not do to

have back drafts. As before intimated, all ducts carrying vitiated air are likely to become coated with foul matter. There should be no possibility of any return of this matter to the rooms.

With properly constructed vent ducts or aspirating chimneys there need not be a back draft under any conditions of wind or temperature.

Every building constitutes a problem by itself, to be solved only after a careful study of all the conditions presented, and then only with a knowledge of the principles of ventilation and heating and the mechanical skill and experience requisite for a practical application of this knowledge to the work in hand.

Every schoolhouse and public building should be planned with a view to a thorough system of heating and ventilation.

Heating and ventilation are closely connected, and should be planned at the same time.

PROJECTIONS BELOW CEILINGS

In the construction of schoolrooms, beams or projections below the ceiling should be carefully avoided to prevent the deflection of the current of air from the inlet, and to avoid causing uncomfortable drafts. If beams project down below the ceiling and are at right angles to the entering air current the air will be deflected and strike the heads of the occupants of the seats a short distance below and beyond the beam. If the room is being cooled off or the temperature of the entering air is lower than that of the room, the uncomfortable drafts will be very apparent.

If the inlet is between two beams parallel to the direction of the current of the incoming air, or between a beam parallel with the outer wall and the wall itself, the air will pass along between the parallel beams or between the beam and the wall to the outer wall opposite the inlet without spreading across the ceiling properly. In such cases an undesirable difference of temperature will be noted in various parts of the room.

In high-studded assembly halls, usually placed in the upper story of a large school building, it is advisable that additional ventilators be placed in the ceiling to carry off an excess of heat or an accumulation of foul air at the top of the room, which is too high to be conveniently ventilated entirely by the vent openings at the floor level. These ceiling ventilators are not intended to be used at all times, but only as the special occasion may require. They should preferably pass up through the roof, or they can be connected with the ducts which take the air from the bottom of the room.

Where gas lights are used the ceiling ventilators should be placed over the groups of burners.

Placing the stacks of indirect radiators or the furnace in the basement in a wrong position, at the base of the warm air shaft, is a source of cold and uncomfortable drafts in the room.

The heating apparatus should always be placed in such a position that the warm air will pass up on the front or room side of the shaft and the cold air used for mixing will pass up on the rear side. If placed so that the warm air comes up on the rear side of the shaft cold drafts will surely be felt.

Deflectors and diffusers, which are generally useless, costly and unsightly devices, placed in front of the warm air inlets will not prevent these troublesome cold drafts.

USE OF MIXING DAMPERS

A mixing damper, which is a device placed near the bottom of the warm-air shaft to regulate the temperature of the incoming air without materially diminishing the quantity, is of great service.

When it is desired to have an entire supply of warm air the chain leading from the mixing damper to the schoolroom is let out, and the mixing damper falls back and prevents the entrance of cold air into the shaft. When it is desirable to cool the incoming air the chain is pulled a little, and cold air is admitted to mingle with the warm air in the shaft.

This damper should not be changed from all warm to all cold, or from all cold to all warm air, by one movement. If this is done the room temperature may be too quickly changed

and the room made too cold or too warm, and a constant variation of the temperature of the air in the room will follow, often accompanied by cold drafts in very cold or windy weather.

When it becomes necessary to change the temperature of the room the mixing damper chain should be gradually let out or pulled in; about one inch or less at a time will generally be sufficient.

When the heating apparatus is properly located at the base of the warm-air shaft the warm air will pass up on the front and the cold air on the rear part of the shaft, the cold air being drawn up and mixed by the ascending current of warm air. If the two currents are not thoroughly mixed in the shaft before the direction of the air currents is changed from a perpendicular to a nearly horizontal direction to flow into the room, the warm air will be on the lower side of the stratum of fresh air and will buoy up and diffuse the cold air.

If, however, the cold air is on the front side of the shaft, when the direction of the current is changed the cold air will be on the bottom of the stratum of fresh air, and being colder than the air in the room, will fall as an uncomfortable draft on the occupants of the seats in front of the inlet. These cold drafts are usually more noticeable at from eight to twelve feet in front of the inlet than in other parts of the room.

OUTLET DAMPERS

An excessive outflow of air through the outlet duct is not desirable, as the air currents are sometimes deflected or short circuited, and the heat and fresh air wasted before having done the work required in the rooms.

This is particularly the case in very cold or windy weather. It also causes an excessive leakage of cold air into the room, and sometimes reduces the temperature of the air in the room to an undesirably low point.

Every foul-air outlet should be provided with a galvanized-iron curved damper, or at least a roller-shade curtain, to regulate the outflow of air.

Judgment must be used by the janitor and teacher in the management of these dampers. During mild weather the damper should be wide open, but during very windy or cold weather it should be partly but never fully closed while the room is occupied.

The proper management of these outlet dampers is a matter that should be fully and carefully explained to the teachers and janitors.

In cold weather, when the room is not occupied, the outlet dampers should be closed in order to prevent an undue loss of heat from the room. While a schoolroom should be thoroughly ventilated during school hours and after the school has been dismissed, the outlet damper should be left open long enough to flush out the room with fresh air, yet to continue the ventilation the whole twenty-four hours will cause an unnecessary expenditure of fuel which would be extremely wasteful.

In some cases gossamer rubber-cloth flap-check valves have been placed at the outlet opening. These things are, however, seldom used by the most successful heating and ventilating engineers and contractors, as they are often worse than useless. It takes a strong current of air to open them, and this means an expenditure of power, either mechanical (by a fan) or of heat, which is a needless waste. Being automatic and intended to prevent back drafts they are liable to close while school is in session and shut off the outflow of foul air, or they may open at night or when the school is not in session and cause a loss of heat from the building and an unnecessary cooling of the rooms. When a strong wind is blowing they often flap open and shut, making a noise which is very objectionable in a schoolroom. With a properly designed and located vent shaft, having either a fan or heat to cause the outflow of foul air, and with a damper to close when ventilation is not required, there should be no use for such worthless and objectionable things as gossamer flap-valves in a vent duct.

PLENUM AND EXHAUST SYSTEMS

Many persons advocate the plenum system, in which the air is forced into a schoolroom and the pressure in the

room is outward, rather than the exhaust system.

In factories and places where machinery and belts keep the air in motion and well stirred and mixed, and where heat is more to be considered than the amount of air for ventilation, the plenum system is well adapted to the purpose. A hot-blast system which will produce excellent results in a factory or large workshop, will not give the desired results in a schoolroom.

In school buildings and audience halls, where a large quantity of moderately warmed air is required for ventilation, it has been the writer's experience that judicious combination of the plenum and exhaust systems gives the best results.

Where the plenum system alone is used and no heat or mechanical means employed for exhausting the foul air, the results have not been as satisfactory as where the two systems were combined.

In the plenum system the air, being under a slight pressure in all parts of the room, is forced out, not only at the vent openings but through every crack and opening, and the circulation is not as good as in a combination system, and a greater amount of heat is required.

Many heating and ventilating systems would have proven failures had it not been for the amount of air supplied by leakage into the rooms.

The writer has found, when measuring the air supply in schoolrooms, that under certain conditions from 50 to 300 per cent. more air was going out at the outlet than was coming in at the fresh-air inlet, the difference being made up by the inward leakage. In many cases where a sufficient supply of air had not been provided the pupils would have suffered had it not been for this inward leakage of fresh air. Even with such a great difference between the air supplied and the air exhausted, the temperature did not vary but three or four degrees, as was shown by thermometers placed on the pupils' desks at the four corners of the room and also on the teacher's desk.

These differences have been noticed in both the mechanical and gravity systems of supply, and are not confined wholly to wooden buildings of cheap construction.

A person not conversant with the facts may well be inclined to doubt the correctness of this statement, but a series of careful tests will convince him of its accuracy.

EFFECT OF WINDS

The force and direction of the prevailing winds in the district where the building is located should also receive careful consideration from the heating and ventilating engineer and the architect. In Massachusetts the prevailing winds in winter are from the northwest.

Where air is forced by a fan through a long duct against the prevailing winds, and where there are several branches taken off, suitable allowance must be made in the size of the ducts, and at each branch where it leaves the main duct suitable adjusting switch-dampers or reducers should in all cases be provided.

Theoretically, the size of the duct to carry a certain amount of air at a given velocity to a given point may be easily calculated; but the engineer or architect must not be surprised to find his calculation considerably out of the way some day when a cold and strong wind is blowing, if the prevailing direction of the wind has not been taken into account when designing the system.

The discharge from a ventilating duct, even when a good fan is provided, should never be directly out from the side or end of a building, when it can be possibly avoided. The writer has seen cases where the discharge has been out from the side of the building against a very strong wind, and when a good fan was running at a high speed no air would be discharged from the outlet pipe. The strong wind blowing directly into the discharge pipe would more than neutralize the power of the fan.

The vent-duct opening should be up and through the top of the building whenever possible to have it so placed.

If on account of the construction of the building it is not practicable to carry the vent opening to the top, but is necessary to discharge from the side or end, a shield or guard should be provided to deflect the wind and prevent it blowing directly into the vent opening.

A strong wind blowing across the top of a chimney or ventilating duct will produce an additional outflow of air.

To illustrate this action, take a glass tube about three-eighths of an inch diameter and about five or six inches long, open at both ends; in the tube, about two-thirds of the distance from the bottom to the top when the tube is held in a perpendicular position, place a light bit of cotton fiber or similar material, then holding the tube before, but not too close to your mouth, give a strong puff from the lungs. The cotton will be forced up and out the tube and fly off in the direction of the current of air from the lungs.

To illustrate the effect of wind striking a projection on or near the top of the chimney or vent shaft, use the same tube and bit of cotton, but hold the hand or some flat article, such as a book or piece of board, in front of and beyond the top of the perpendicular tube; a strong puff from the lungs will cause the air to strike the obstruction and be deflected down into the tube, carrying the cotton out at the bottom.

It sometimes happens that one vent flue in a school building will cause trouble by having a down draft, while the other will be doing satisfactory work. If an inspection is made of the top of the flue it will probably be seen that some projection is above or against one side or end of the top, against which the wind strikes and is deflected down the vent flue.

WHEN SMOKE AND VENT FLUES SHOULD NOT BE CAPPED

The practice of extending the smoke flue up above the level of other parts of the same stack should be avoided. Unless absolutely called for by some special construction of the building as regards towers, etc., the top of the smoke and vent flues, if constructed of masonry, should not be capped or hooded over. The danger of water or snow going down the brick flue is very small. The bricks, being porous, absorb the moisture, which is soon evaporated by the current of warm, dry air passing up the flue.

Vent flues and chimneys should when practicable be carried well above the highest part of the ridge.

The writer recalls a building designed by a well-advertised firm of architects in which the system of heating and ventilation was designed by a heating and ventilating engineer who has frequently been quoted as an expert.

The vent shaft was of large dimensions; in it were the ventilating openings from several rooms, and there were no divisions or withes in the shaft. The top was considerably below the ridge of the building, and was capped with blue-stone flagging. There were two good-sized openings on each side under the cap.

A considerable quantity of steam-pipe was placed in a coil around the sides of the shaft and located just above the floor of the first story of the building. Flap valves were placed over the room outlets to prevent back drafts. When the wind was from a certain direction these flap valves were kept closed by the down drafts, thereby shutting off the ventilation from the schoolrooms.

Complaints of bad ventilation continued to be made. More steam pipes were put in the shaft till about 300 square feet of radiating surface had been put in the shaft.

The complaints continued, and the writer was called by the school authorities to see what was the trouble. The examination was made on a cold day when a strong wind was blowing. The steam was turned on full head in the vent-coil heaters (the boiler pressure being ten pounds by the gauge).

Commencing in the basement at the lowest opening into the vent shaft, the flap valves were found to be closed, and on lifting them and placing an anemometer in front of the opening so made, the air was found to be com-

ing down and into the room at a velocity of over 500 feet per minute and at a temperature of 28 degrees F.

The school authorities were advised to remove the blue-stone cap, brick up the openings in the shaft, and carry it above the ridge; also to remove the flap valves. This was done, although the architects protested that it would injure the architectural appearance of the building. Galvanized iron dampers were placed at the room outlets where the flap valves had been removed, and part of the steam-pipe was taken out of the shaft.

No trouble was afterward found in having a good outflow of foul air from the schoolrooms, and no back drafts were noticed.

GALVANIZED IRON VENT FLUES

Where galvanized iron vent flues are used it is well to cover them with a cap which should project well beyond the sides of the duct. It is essential that sufficient clearance space be allowed between the cap and the top of the vent flue. How frequently we see flues of ample size that have a cap close down to the top of the flue with but little chance for the air to escape.

It should be remembered that the openings on all four sides are not always available, and that only about one-half of the area can be considered as effective, that is, the leeward half, or the part in the direction the wind is going.

METHODS OF TESTING COURSE OF AIR

Whether the warm-air inlets and foul-air outlets are properly located can be determined by wrapping in a piece of paper dipped in nitrate of potash and then dried, or in a piece of tissue paper, a small tablespoonful of gunpowder, placing it on a piece of sheet metal or board held about two feet in front of the warm-air inlet, setting fire to the paper and watching the circulation and diffusion of the smoke.

A sponge saturated with ammonia and held over a dish of hydrochloric (muriatic) acid will also show the circulation of air, but is not as convenient or desirable as the powder smoke test.

The down or coma of the milkweed can also be used to show the movement of air currents in a room, but not as fully as the powder smoke test.

The movement of the air currents by the powder smoke test may best be observed by taking a position at the inner angle of the room, as selected that the light from the windows in the outer walls will best enable the observer to see the movement of the smoke.

The action of the open windows on the circulation of air in a room will become apparent by using the powder smoke test.

Heating and Ventilating the National Park Bank, New York

A System of Direct Radiation With Auxiliary Indirect Apparatus for Ventilating

Among the notable New York buildings of recent construction the New National Park Bank is especially interesting on account of its unusual shape and interior arrangements. The counting room, for instance, is a lofty apartment occupying fully one-half of the entire building, while the basement and subbasement areas are devoted largely to the use of the bank's clerks, in addition to the vaults and safe deposit boxes.

One blower, however, serves to supply fresh air to the entire building, although the exhaust ducts are connected to four exhaust fans on the roof.

HEATING SYSTEM

The system of heating the building is by means of direct and indirect radiation. The use of boilers is obviated by taking steam from the street mains of the New York Steam Company. This steam passes through an 8-inch Kieley reducing valve, reducing the pressure to 8 pounds at the source of supply. The main supply and return pipes, to-

gether with all machinery, are located in the sub-basement. The return pipes discharge the water of condensation through a cooling coil into the sewer. This cooling coil is located near the cold air chamber and has 500 square feet of surface arranged so that the cold air supply will pass over the coil. In connection with the coil are two 6x4x6

NEW PARK BANK BUILDING. THE BUILDING IS IN THE FORM OF A T

steam pumps to discharge the water of condensation into the sewer. The exhaust connections from the machinery are carried above the roof. Steam for the pumps is supplied from a special high-pressure main, as shown in the illustration. In the building are 59 direct radiators and coils; most of the radiators are 38 inches high, except some that are located under the windows. All recesses, where radiators and coils are located under windows, are lined on the sides, banks and tops, first with asbestos board, 1/8 inch thick, and over this galvanized iron.

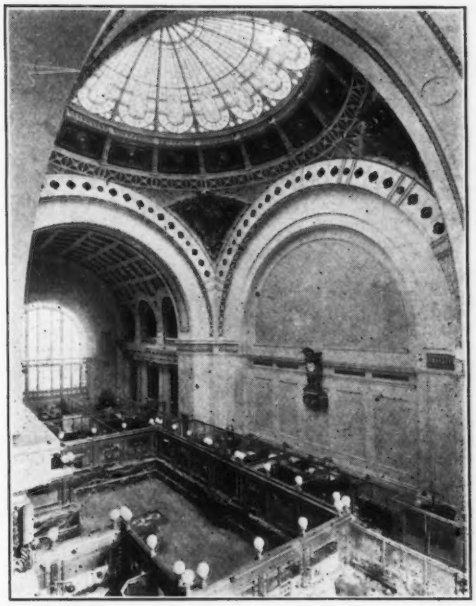
INDIRECT RADIATION.

The main banking room is heated entirely by indirect radiation, and for this purpose 18 stacks of indirect radiators are suspended from the sub-basement ceiling, directly at the mouths of the heating flues and registers which they supply. These sections are built up 4 inches on centers and contain 550 square feet of surface and are properly encased in galvanized iron casings, allowing air spaces of 1 inch each on the side of the stacks and 8 inches on the tops and bottoms.

Most of the top heat flues are near the ceiling, but in the banking room they are located 20 feet above the floor. The bottom heat flues terminate about 2 feet above the floor of the different rooms which they supply.

PIPING

Although the steam is taken from the street mains, the piping in the sub-basement is so arranged for possible future connection to boilers. This is accomplished by carrying the main steam supply pipes from the reducing valve to the boiler room. The



INTERIOR VIEW NEW PARK BANK BUILDING, SHOWING DOME OVER MAIN BANKING ROOM

main is gradually reduced as branches to stack radiators and risers are taken off. The main return pipe is run near the floor and is of two sizes correspondingly smaller than the main supply pipe over 3 inches in diameter and one size smaller for all pipes under 3 inches in diameter.

The special 2½-inch high pressure line for the pumps connects also with

the hot water tank for summer use only. For winter use, another connection is made between the hot water tank and the low pressure main.

FRESH AIR SUPPLY

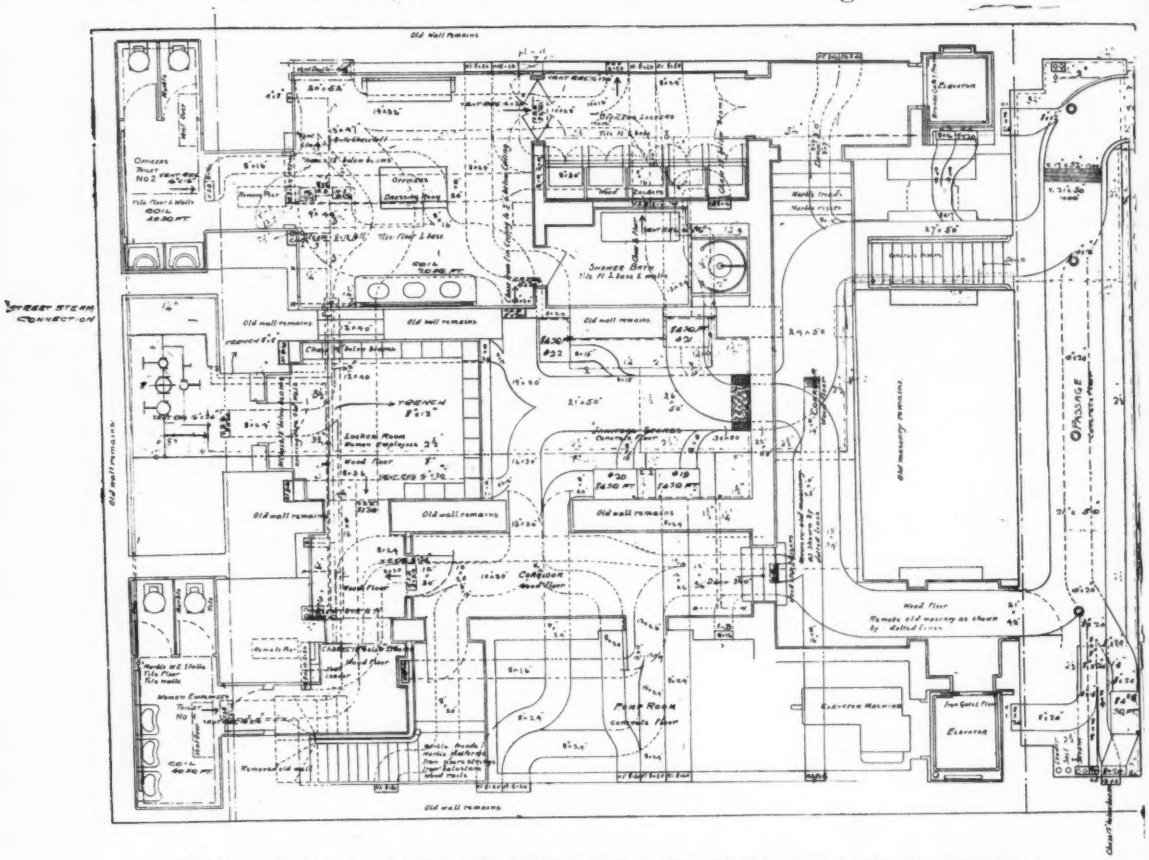
Fresh air is carried from the roof through a cold air shaft, which is provided with a copper cap and hoods for protection from the weather.

On reaching the sub-basement, the cold air passes through a set of filters into a 9 foot steel plate fan, 4 feet wide at the inlet, whence it is forced through tempering coils into the main tempered air ducts. There is rather an extensive system of these ducts, as will be seen from the sub-basement plans. All branches from the main ducts have dampers to regulate the air supply.

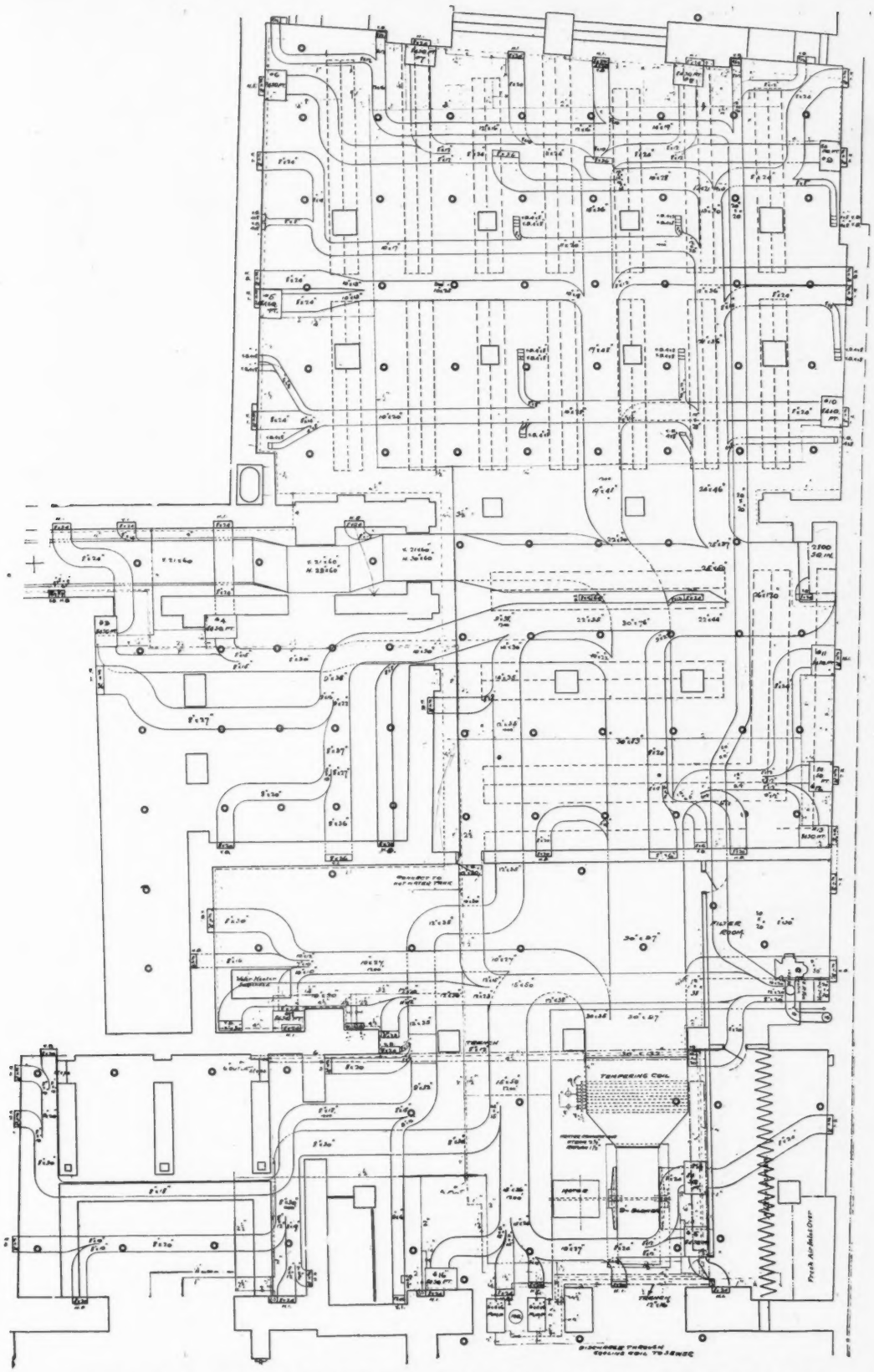
TEMPERING COIL AND FILTER

The tempering coil for the ventilating system is built of 1 inch pipe on a brick foundation and contains 1,600 square feet of heating surface. This coil is built on corrugated sectional bases, each base 6 feet long, two having 4 rows of pipe 11 feet long and two having 2 rows 11 feet long, making a total of 12 pipes wide, all being enclosed in a steel plate casing, connected with the discharge outlet of the fan. This housing connects with the main air distributing duct.

The air filter is built of 52 leaves, each the full height of the room. Each leaf is divided into two sections for convenience in handling. They are made of white pine, over which are placed 1 inch mesh galvanized wire screens. Over the wire screens is stretched fine cheese cloth fastened to the wooden frame with brass nails and felt. A duplicate set of these leaves are provided to replace the originals when they are being cleaned.



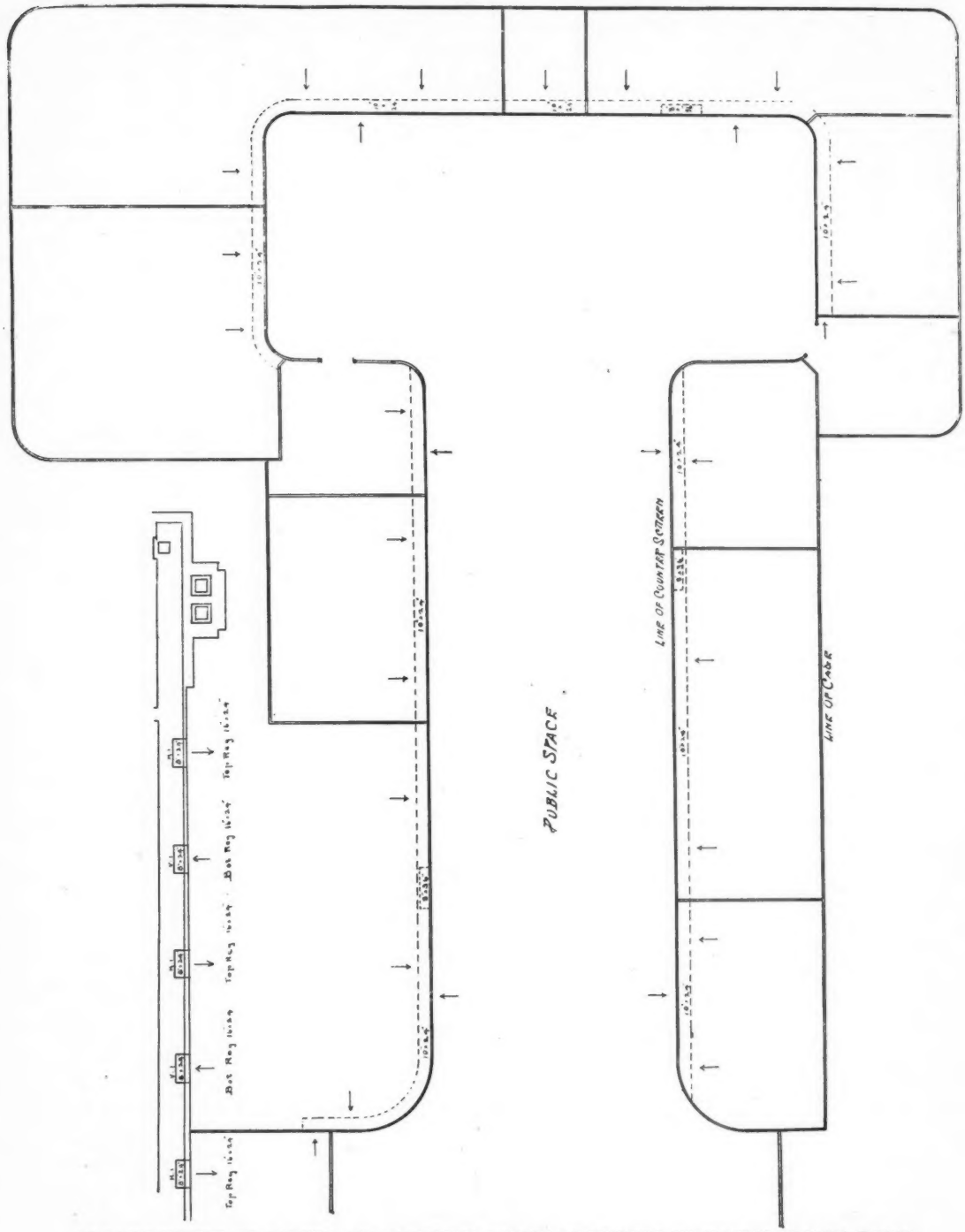
PORTION OF SUB-BASEMENT OF NEW PARK BANK BUILDING, SHOWING GENERAL ARRANGEMENT OF VENTILATING SYSTEM. THIS VIEW IS OF THE BROADWAY FRONT



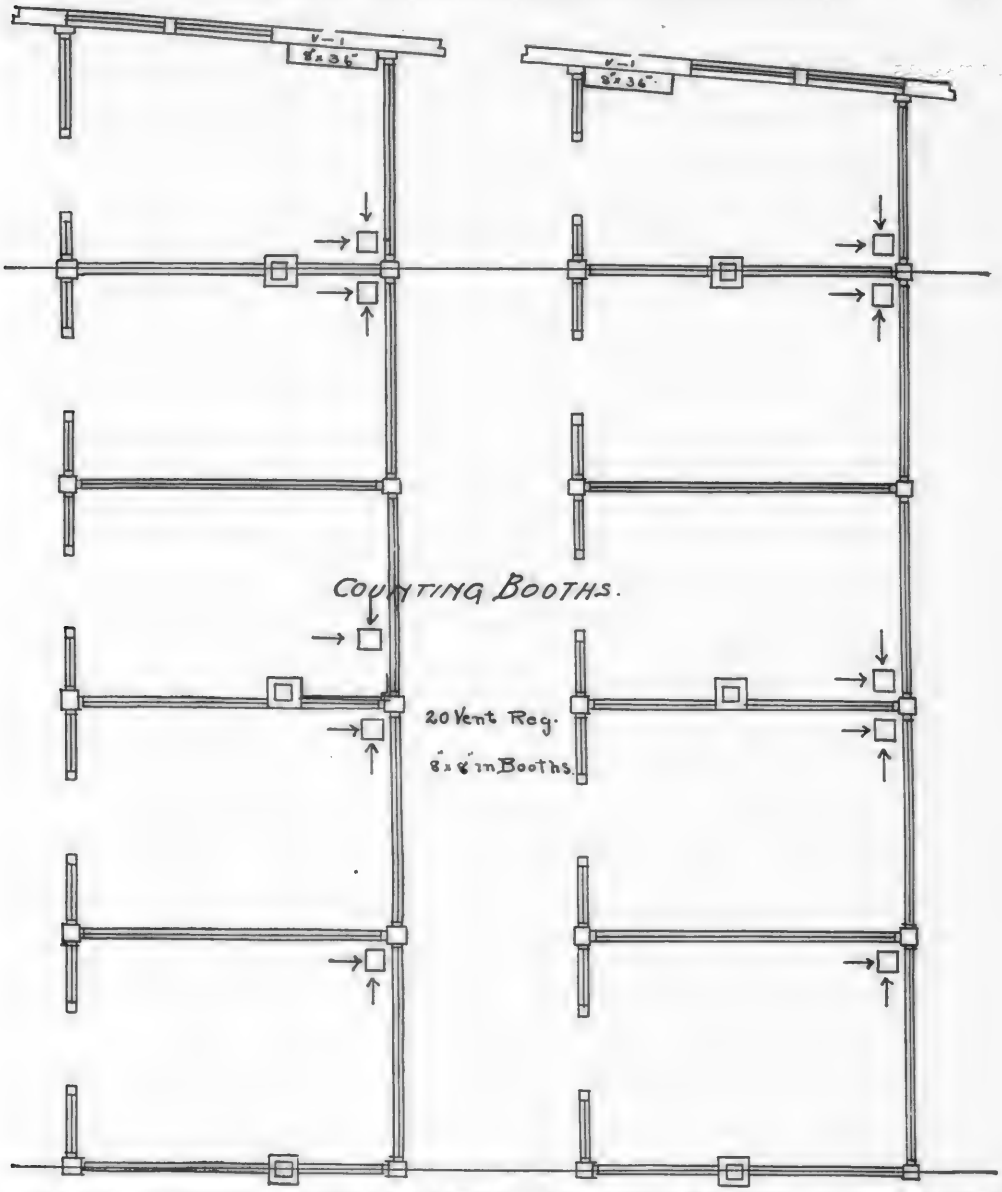
PORTION OF SUB-BASEMENT OF NEW PARK BANK BUILDING, SHOWING GENERAL ARRANGEMENT OF VENTILATING SYSTEM. THIS VIEW IS OF THE NORTH AND SOUTH WINGS

SUPPLY AND EXHAUST FANS

In addition to the 9 foot supply fan in the basement are three 72-inch and one 54-inch Blackman exhaust fans located on the roof. The exhaust fans are supported from the roof beams and are connected with the ventilating ducts and flues and with the collar of the discharge cap. There is also a 40 inch steel plate exhaust fan for use in cleaning the air filters. The exhaust inlet is connected with a hood having the same dimensions as one of the air filter frames. This hood is so arranged that one of the



ARRANGEMENT OF INLETS AND OUTLETS UNDER COUNTERS IN MAIN BANKING ROOM, NEW PARK BANK BUILDING



PORTION OF COUNTING BOOTHS IN BASEMENT. THE VENT REGISTERS IN THESE BOOTHS WERE PLACED IN THE TOPS OF SMALL STANDS TO PREVENT COINS ROLLING INTO THEM

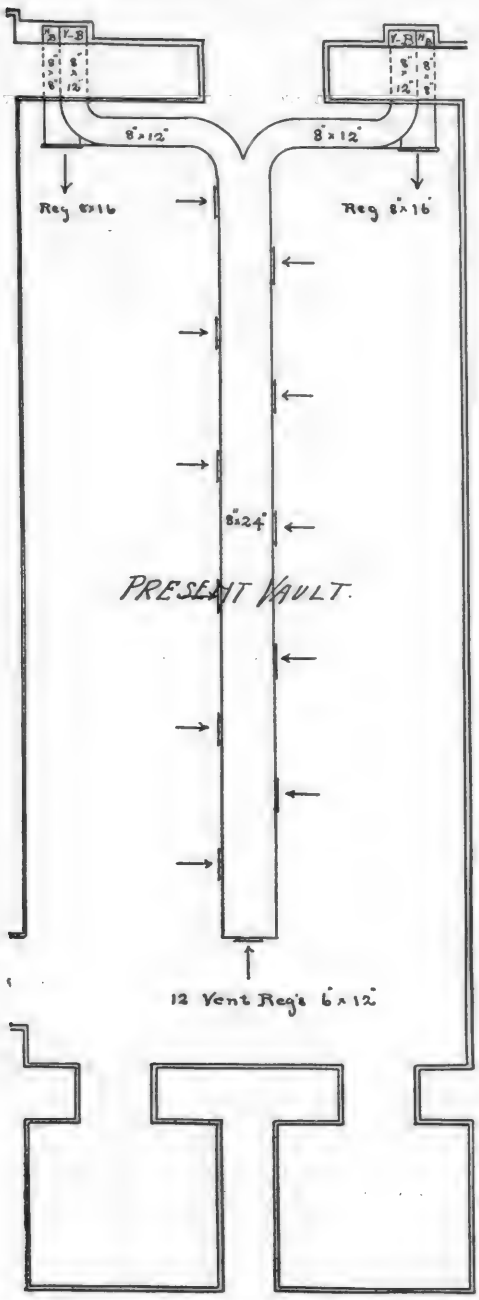
filter frames may be placed against its edges for cleaning the cheese cloth and discharging the dust through the fan and into the discharge duct as shown. The arrangement of the hood makes it possible to easily remove a frame against the air pressure with the fan running at full speed. The hood is made of galvanized iron and the discharge of fan is connected with the discharge of a circular duct 16 inches in diameter, which runs vertically to the roof and has a discharge cap placed 6 feet above the roof.

THE MOTORS

For driving the supply, exhaust and cleaning fans, 5 electric motors are furnished. The 9 foot blower is connected with a 15 H. P. motor, while a 5 H. P. directly connected motor drives the filter fan. Three 10 H. P. motors drive the three exhaust fans in the attic. The 5 H. P. motor on the 40 inch fan has a speed of 1,214 revolutions per minute.

THERMOSTATIC CONTROL

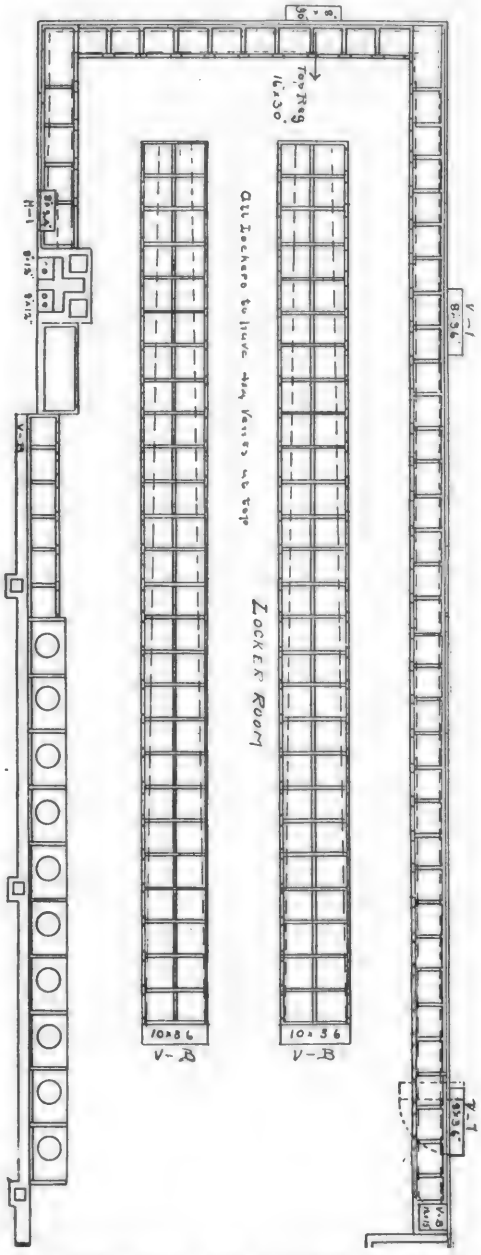
The temperature of the entire building is automatically controlled.



VENTILATION OF VAULT IN NEW PARK BANK BUILDING

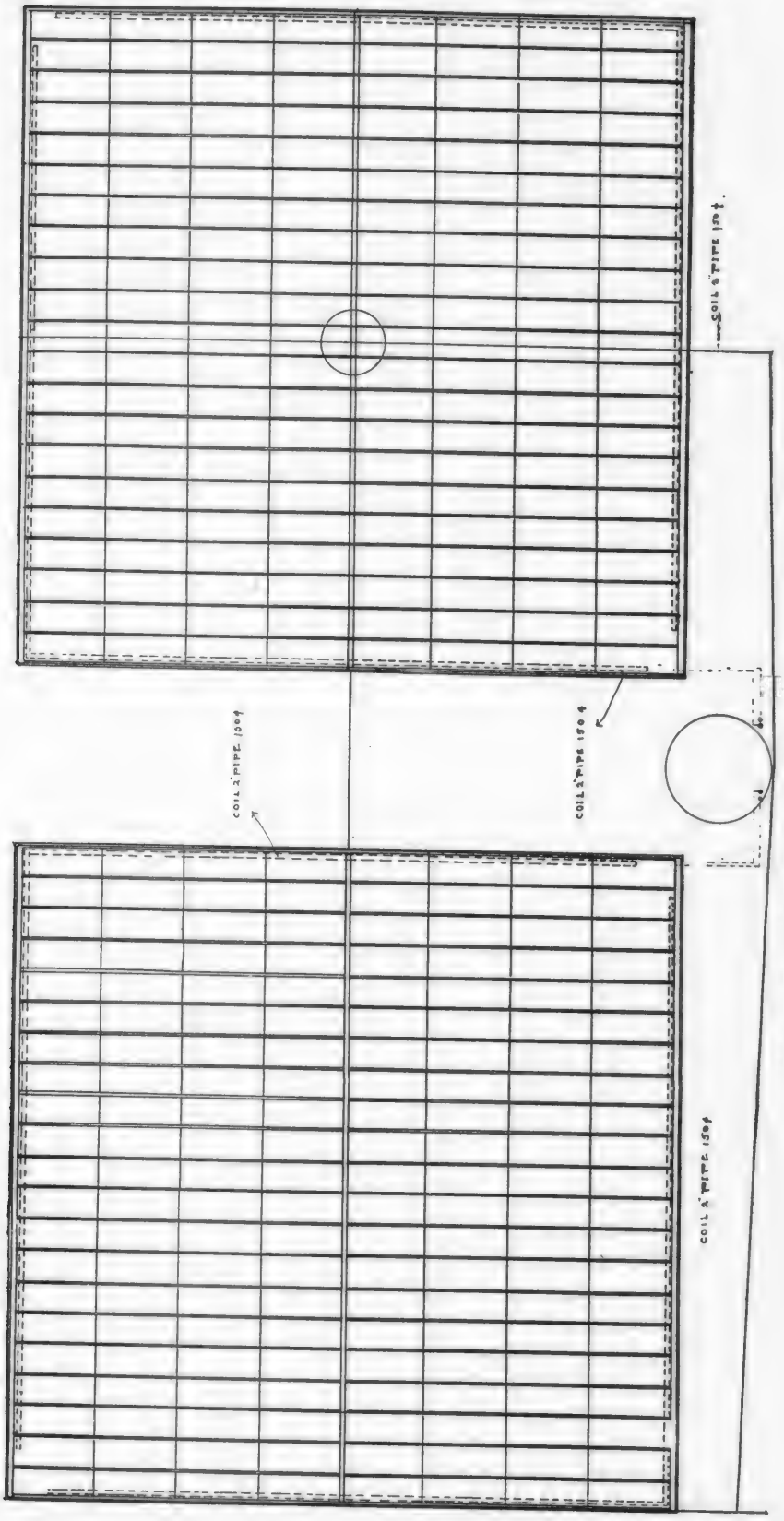
In connection of the tempering coil are two pneumatic thermostats with diaphragm controlling valves. One of these is located in the cold air supply and controls two valves on the inside group of the tempering coil. Another thermostat, in the warm air duct, leading from the tempering coil, controls four valves on the two outside groups of tempering coils.

Each group of tempering coils is provided with an hermetic vapor valve, properly connected with a compressed air line of the heat control system. The main building is controlled by 43 thermostats connected with 65 heat sources. Baker, Smith & Co., of New York, were the contractors for the work.

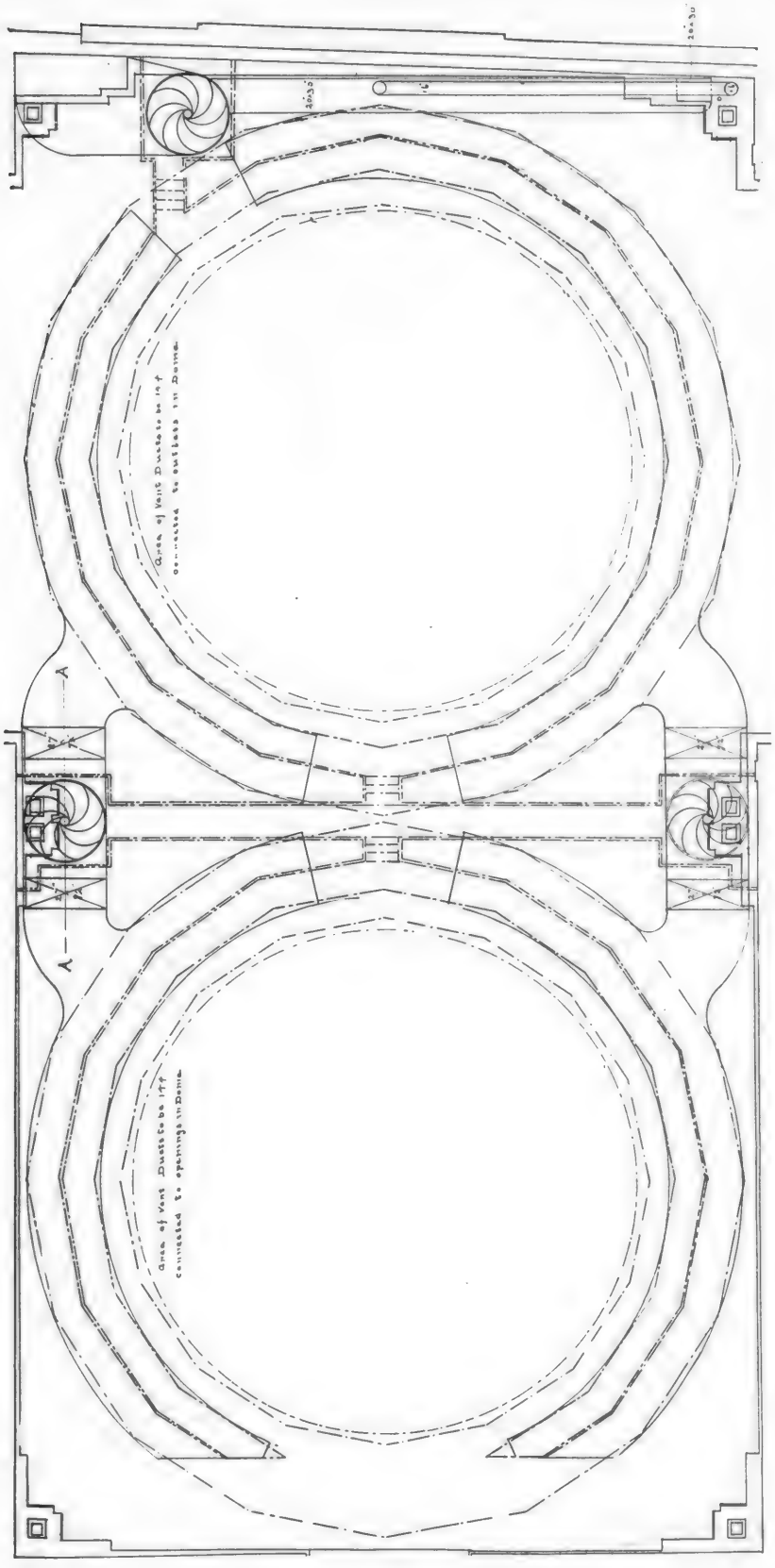


VENTILATING THE LOCKER ROOM IN BASEMENT

This room has no direct connection with the outside air, Each locker has an individual outlet.



SKYLIGHT COILS IN DOMES OF NEW PARK BANK BUILDING



ARRANGEMENT OF EXHAUST DUCTS AND FANS OVER DOMES IN NEW PARK BANK BUILDING

A Scotchman's Notes on Ventilation*

By Alexander Mackenzie

Fresh air and fresh water are the freest of God's gifts, yet how often do we see the necessity for fresh air ignored. In crowded rooms, in railway carriages, and such like places, you will see the condensed breath of the occupants, as water, running down the inside of the windows and walls—a sure sign of a foul atmosphere, and the sooner the windows are opened the better for all concerned.

FIREPLACES AS VENTILATORS

That special provision for heating, as well as ventilation, of large and crowded buildings is necessary most people will admit. As regards ordinary living rooms, the requirements are not very great, and simple arrangements are usually found ample for all purposes unless in very large or crowded apartments. The simplest method of warming a room is by an open fire in a grate. While theoretically this may be most wasteful of fuel, it must be admitted that it is a most useful, pleasant, and healthful way of ventilating, as well as warming, an ordinary room. The heat also is radiant heat, which is similar to the heat we derive from the sun. If the fireplace, being low down, is not sufficient to carry off the foul air from a room because of the number of occupants—and most of the foul air is undoubtedly higher up—the ventilation can be assisted by inserting a ventilating grating into the side of the chimney near the ceiling, this grating being provided with mica or other flaps to prevent a blow back.

For inlet ventilation in such rooms there are always the chinks of the doors and windows, although there are still, I suppose, some people who believe in rubber draught tubing, sand bags, and such contrivances. If more inlet for fresh air is required, the simplest arrangement is to open the window, or let air in at the counter-check of the window by inserting a suitably shaped piece of wood at the sill. The air coming in at the counter-check is thrown upwards, and is not felt as a cold draught, because the fresh air diffuses itself among the air already in the room before coming in contact with the occupants. It is not, however, a desirable arrangement to blow the fresh air in among the foul air in this way, although for a room with few occupants no great harm may follow.

OPEN WINDOWS IN BEDROOMS

For bedroom ventilation I consider nothing can be better, if as good, as the open window. In these days we are having the virtues of fresh air continually pointed out to us, and very many of us are already converted. We spend probably eight hours out of each twenty-four in our bedrooms, and unless we have abundance of ventilation, the atmosphere in an ordinary-sized room will become very foul, even with one person, not to speak of overcrowding. Unless the window is facing a strong wind, you will find that it is better to have it well opened instead of only a small piece. A large volume of air all over the person is not objectionable, while a small streak of air striking the body only in one place is. With plenty of bed clothing there is no reason why all persons in good health should not follow this practice of sleeping with the window open. With sick persons it is an entirely different matter, depending upon the nature of the trouble.

THE CAUSE OF BACK SMOKE

We may take it, then, that in ordinary living rooms no very special provision is required for ventilation or heating, but that the usual fires and windows will answer quite well. It would, however, be well to try to teach the public that they

*From a paper read by Mr. Alexander Mackenzie, of Mackenzie & Moncur, Ltd., before the Edinburgh Sanitary Society, February 10, 1906.

should not attempt to seal up all crevices with draught tubing, etc., and to bear in mind that no being can live and no fire can burn in the fireplace of a room hermetically sealed all except the chimney. As an example of the necessity of inlets, consider a tenement house with all doors and windows tightly shut and having a fire in the kitchen range, but nowhere else. What do we find? The fire draws in its necessary supply of air down the chimney or chimneys which are not in use, these being the easiest places for the air to get in at. If there happens to be smoke coming out of another chimney beside those that are acting as inlets, it is drawn down into the house, and goes by the name of back smoke. It would, therefore, be much better to allow air to come in at some other places rather than down the unused chimneys. I mention this to show that inlets are always necessary where fires are burning, and much more so when there are living beings in the house or room. In large apartments additional heating is very desirable at the parts of the rooms furthest from the fires, and preferably at the windows. In entrance halls, staircases, and corridors of villas and mansions special provision for heating is particularly desirable, as it increases the comfort of the whole house. Generally speaking, I believe in simple arrangements in all ordinary dwelling-houses. I see no necessity for making our lives too artificial.

If we leave dwelling-houses and consider churches, hospitals, halls, schools, etc., we may take it that those buildings which are most crowded for the longest period at one time are those which require most ventilation. Churches are only occupied for about one and a half hours at a time, and are not by any means usually crowded. Hospitals are not crowded, and are kept scrupulously clean, but for curative purposes plenty of fresh air is a great advantage. Ample ventilation is also necessary in order to carry away the exhalations and effluvia given off by the patients, these being more harmful than from people in good health. Theaters and halls are usually crowded, and for a fairly lengthened time. They, therefore, require a good system of ventilation. Schools in my opinion need ample ventilation, more than any other class of buildings, and, if we consider them carefully, I think that the same principles can quite well be applied to other buildings as circumstances require. Even under the present improved regulations, schoolrooms are usually well filled with pupils, and for fairly long periods. Also the children are not always as clean and fresh as they might be, especially in the poorer districts. For ordinary smaller-sized schools it is generally found that an arrangement of automatic ventilation is sufficient, but for larger schools, especially in towns where the atmosphere is less pure than in the country, some system of mechanical ventilation is now usually employed.

SOME OF THE METHODS OF VENTILATION IN USE

For all ventilation, whether automatic or mechanical, there must be both inlet and outlet openings, and the air coming in should be warmed in winter. With automatic ventilation the inlets are sometimes brought in through the side walls by Tobin tubes or inlet brackets, but when the ventilation and heating are combined, as they should be, the fresh air is brought in at the back or through the centre of radiators or coils of pipes, so that the temperature of the incoming air may be raised as required. The Tobin tubes and inlet brackets are open to the same objection as the inlets at the counter-check of windows. The fresh air is discharged in an upward direction in order to avoid causing draughts, and it is thereby mixed with the foul air already in the upper part of the room. The outlet for the foul air is, with automatic or natural ventilation, always taken off at the top of the apartment, and the less

obstruction there is to the outlet the better. An open hole is not permissible, but there are many simple outlet ventilators that can be got or made which keep out rain and wind, and this is the main consideration. Patent air-pump ventilators will not cause an upward current in still weather, and that is when ventilation is most required; they are rather a drawback in such weather. There should not be two outlet openings from one apartment to the outside. There may be two or more openings on the ceiling with the shafts joined together to one outlet on the roof; but if there are two separate openings to the outside, the one may act as an inlet and the other as an outlet. This is especially liable to happen if there is a deficiency of proper inlets below.

THE CAUSE OF THE CIRCULATION OF AIR

Now, what causes the air to flow through this room provided with inlet and outlet ventilators is simply the rarification of the air that takes place. First, by the heating arrangements; second, by the heat of the bodies of the occupants; and third, by their breath, which is about 90 degrees Fahr. when expired. This warmed, rarified air does not rise of its own accord, but is pressed upwards by the heavier and denser cold air outside pressing in through the inlets at the bottom, and forcing the foul air out at the top—just the same principle as regulates the upward current or draught in a chimney with a fire at the bottom. If this is borne in mind, there should not be much difficulty in ordinary small schools or other buildings, except that the inlets have to be arranged where they are least likely to be objected to by people who feel draughts, or others who, whenever they see a ventilator, imagine they feel draughts.

USE OF ELECTRIC FANS

Let us now consider what is done when the natural draught is not sufficient for the number of persons occupying a building, and something must be provided to assist or augment the natural ventilation. Sometimes a coil of steam or hot water pipes is placed in the outlet shaft to induce a stronger upward current, and with very good results. A heated iron chimney inside a surrounding air space constituting an extraction ventilation shaft is also very effective. In other cases an even stronger current than these provide may be required, and a fan has to be employed. Since the introduction of electric light into our large, and also many of our smaller, towns, the application of ventilating fans has been very much simplified. The electric current is now made use of to drive the fans by means of electric motors combined with the fans, or separate, and driving with belts.

If mechanical arrangements are required, the most natural manner in which to increase the amount of fresh air passing into and through a building is to assist the automatic or natural ventilation. This can usually be done by placing a fan in the outlet shaft to increase the rate of extraction. With the extraction system windows can be freely opened in summer if desired, and what can be better in almost all circumstances in warm weather than a free flow of air direct from the outside? Again, if any mishap should occur to the fan or motor (and mishaps are liable to occur wherever there is machinery), there will still be the natural upward current available till matters are rectified.

THE EXTRACTION SYSTEM

For the warming of rooms of schools or other crowded rooms where the automatic or extraction system of ventilation is adopted there should be a sufficient amount of heating arranged round the sides of the room as far as possible; and a fair proportion of this should be so arranged that the fresh air coming in at the inlets will pass over or through it, and so become warmed before spreading through the room.

More heating is of necessity required when the ventilation is increased in quantity. Ventilating radiators of various types are made for this purpose. Those with flues through them are now being abandoned because of the difficulty of cleaning them, and the ordinary open-looped type of radiator is being used, either with removable plates in front to deflect the air up through the radiator or with loose baffle plates set in between the columns of the sections. Another even simpler type of radiator has been brought out recently by an English manufacturer for hospital purposes, and is still more easily dusted and kept clean than the ordinary type. This pattern can also be fitted with the removable deflecting plates in front if required. I should here state that the word "radiator" is really not a correct designation of these articles; they do not heat by radiation, but by convection.

By this arrangement of heating the temperature of the various rooms can be regulated and controlled independently by having valves on the pipes or radiators in each room. Where the rooms are facing in several directions, some facing the sun, and some to the north, never getting any sun, it is very desirable that there should be this control.

ADVANTAGES AND FAULTS OF THE PLENUM SYSTEM

The propulsion or plenum system has many very attractive features as well as distinct advantages; it also has some drawbacks. In this system the inlets for the fresh air coming into the rooms are almost invariably placed high up near the ceiling, or at a lower level, but discharging towards the ceiling. The extract openings are at or near the floor on the same side of the room as the inlets, and from there the extract shafts are carried to the roof, where they may discharge into the open roof space, and thence through turrets to the open air, or they may be joined up to the turrets with closed shafts. In some cases a fan or fans may be applied to the outlet to help the fans blowing in at the other end of the system. The fresh, warm air comes in high up, spreads over the upper strata of the room, and gradually descends towards the outlet near the floor, with practically no draught.

The advantages of the plenum system are—

1. The air can be taken in where the purest air can be got. In certain town localities this is an enormous advantage.

2. The air can be washed and filtered to remove solid impurities, and humidified also, if required.

3. The air in the rooms being under slight pressure, the inflow of fresh air is accomplished with the minimum of draught. This is an undoubted advantage.

4. At all crevices of doors and windows, instead of cold, fresh air coming in owing to the slight pressure inside the rooms, there is a current passing outwards.

The disadvantages are several—

1. The fresh air being blown in near the ceiling, or in an upward direction, it mixes with the foul air, which, when given off by the body, is about 90 deg. Fahr., and tends to be pressed upwards by the cooler air in the room. There is thus a considerable amount of diffusion, the foul air contaminating the fresh air to such an extent that it is only by largely increasing the quantities of air forced in that efficient ventilation is procured. Again, in summer, when the air being blown in is cooler, and consequently denser than the air in the room, it will not spread over the upper strata as before, but will drop down through the warmer air with less diffusion, and move directly to the outlet without spreading through the room.

2. If there is any breakdown of machinery, the whole system of the heating, as well as the ventilation, is useless for the time being.

3. Owing to the pressure that has to be kept on the air in the rooms,

the windows must be always kept shut, and the doors as much as possible. This, as regards the windows, I consider is a very unfortunate state of affairs, because of the unconscious influence it must have on the children. As already mentioned, there is in the present day a great cry for fresh air and open windows in our homes, but how can this be expected from the rising generation if they are brought up in a school where every window is religiously kept shut?

4. The flues from the fan to the classrooms are conveying fresh air, but although the large mains, if they are properly built, can be kept clean, the branch flues or ducts in the walls cannot be, and are bound to get foul in the course of time.

5. The fifth objection, although I don't consider it is of the greatest importance, is certainly one that cannot be ignored, that is, the cost. The cost of working, as well as installing, the plenum system is very considerable. The working costs are greater because of the greater quantities of air to be moved and warmed to the requisite temperature. This large quantity of air, you will observe, is not required so that each pupil will actually breathe and use some 1,500 or 2,000 cubic feet per hour, but because this quantity is found necessary with this system to maintain the air in a sufficient state of purity. The amount of air actually passed through the lungs of an adult person is only about 21 cubic feet per hour.

TEST SHOWING COMPARISON OF THE TWO SYSTEMS

For a comparison of the working costs of the two systems, I have taken two typical schools in Edinburgh as examples, one with the extraction system of ventilation and one with the plenum system—both have steam heating. The school with the extraction system has the air in the classrooms changed on an average five times per hour, giving an air supply of 803 cubic feet per pupil per hour, at a working cost for fuel and power to drive the fan of .38 of a penny per pupil per week in the present winter weather. I have had the air analyzed in several classrooms by an eminent analyst, and find that the carbon dioxide in the classrooms of this school averages 7.3 volumes per 10,000 volumes.

The school with the plenum system has the air in the classrooms changed on the average 9.26 times per hour, giving an air supply of 1,646 cubic feet per pupil per hour, at a working cost for fuel and power to drive the fan of 1.75 pence per pupil per week in the present winter weather. The analysis of the air in the classrooms of this school, taken the same day by the same gentleman, gives an average of 6.7 volumes of carbon dioxide in 10,000 volumes.

The result in the purity of the atmosphere in the classrooms is that the plenum system gives .6 of a volume less carbon dioxide per 10,000 than the extraction system, but this is only attained by supplying about double the quantity of air at four and a half times the cost.

I have also some data from another plenum-ventilated school, but have no analysis of the air. In this school the air in the classroom is changed 5.68 times per hour, giving an air supply of 1,004 cubic feet per pupil per hour, at a working cost for fuel and power of 1.2 pence per pupil per week. If the quantity of air supplied to this school was equal to the other one quoted, the cost in proportion to the above would be 1.97 pence per pupil per week.

FAVORS EXTRACTION SYSTEM

From my general experience, and also judging from the foregoing figures, my opinion is that the large quantities of fresh air found to be required for each scholar or occupant of a building, when the plenum system of ventilation is used, are only necessary to keep the air fresh because of the principle of the system; and that if the extraction system, which is the automatic or natu-

ral system assisted by mechanical means, is made use of, the same results can be obtained at a fraction of the cost of working. If a building for a small number of people can be ventilated satisfactorily by natural or automatic arrangements, having inlets at the bottom and outlets at the top, where the foul air is always found when a room is occupied, it seems reasonable that when we want to increase the amount of ventilation we should rather assist the natural current instead of going contrary to it.

GENERAL CONTRACTOR INSTALLS PART OF HEATING APPARATUS

The cost of installing the system has also to be considered. Unfortunately, with the plenum system it is almost impossible (in Scotland) to get at the actual cost, because a very large part of the expense is incurred in making a large heating chamber, main and branch air ducts, both for fresh and foul air. This work is carried out (in Scotland) by the general contractor for the buildings, and the cost is submerged and lost sight of in the general cost of the building. No doubt it could be ascertained from the contractor's schedules, but I don't know that this is ever done. I have no hesitation in saying that the cost of the builder's work in forming the heating chamber, ducts, etc., for a plenum system will amount to about 60 to 80 per cent. of the cost of the engineering part of the work, perhaps even more if the ducts are built of white enameled brick, as is often advocated. In the case of the extraction system, I do not think these supplementary works will generally amount to more than about 10 or 15 per cent. on the engineering contract. There is, however, no doubt that the plenum system will give better results in a school situated in a part of the town where the general air is more foul, and where it is, therefore, very desirable to filter and cleanse the air before it passes into the classrooms.

I am, however, inclined to think that if the arrangements for filtering and heating as used in the plenum system had the fan at the other end of the ducts, extracting the foul air instead of blowing in the fresh air, we could have quite as good results at less working cost. We would certainly have the disadvantage of the cold air coming in at the crevices of the doors and windows, although I do not consider this a fatal objection to the proposal.

One advantage of such an arrangement would be that in a special emergency the windows could be opened to clear out or cool down the air in the room without upsetting to any extent the ventilating arrangements of the other rooms.

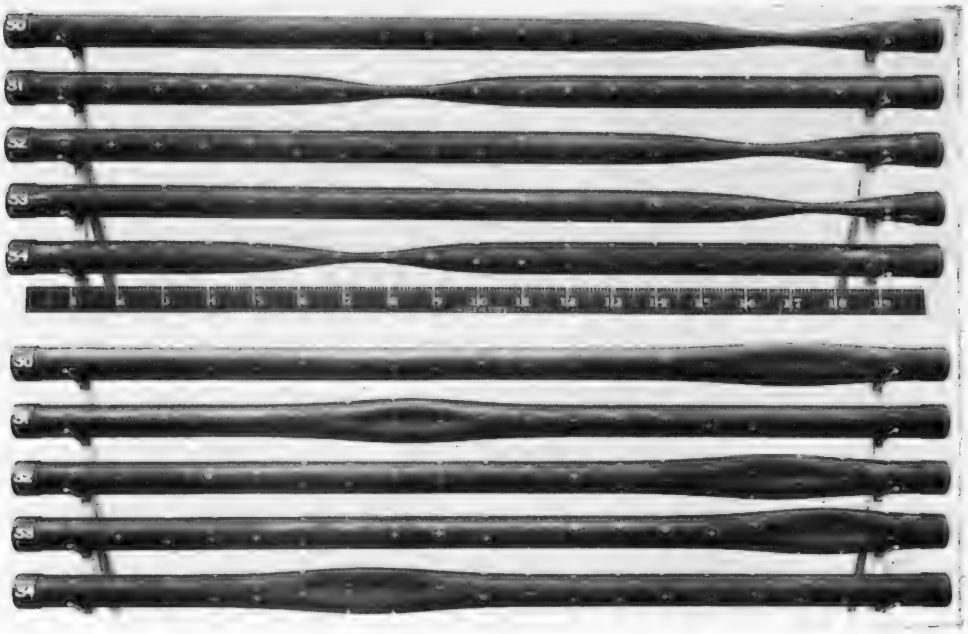
SCHOOLROOMS SHOULD BE FLUSHED WITH FRESH AIR

In connection with the ventilation of schools generally I see that within the last few days letters have been appearing in the public papers regarding the flushing of the schools with fresh air when unoccupied. I have repeatedly spoken about this to schoolmasters and others. Why should not the windows be opened whenever the children leave, and allow an abundant flow of fresh air through the school? In fact, the windows ought to be open more or less continuously from Friday afternoon till Monday morning, as well as other days between and after school hours. The blinds also should be pulled up to the top to allow the light and heat of the sun into the schools at the same time. The blinds are there to be used during school hours for the comfort of the scholars and teachers, but should not be pulled down merely to let outsiders see that the school is closed. There is not even the housewife's excuse that the color will be taken out of the carpets. Some of our old schools in the city were put up before so much attention was given to ventilation, and if this flushing was systematically carried out it would be of very great advantage.

Collapsing Pressures of Bessemer Steel Lap-Welded Tubes Three to Ten Inches in Diameter*

By Prof. Reid T. Stewart, Allegheny, Pa.

This research was undertaken for the purpose of supplying an urgent demand for reliable information on the behavior of modern wrought tubes when subjected to fluid collapsing pressure. Every means known to engineering science that could aid in the accomplishment of this undertaking has been used, and every possible effort made to get at the truth and have the research yield trustworthy data. It was planned and executed under the immediate direction of the author, at the McKeesport works of the National Tube Company, and has occupied for its completion, during a period of four years, the time of from one to six men.



TWO VIEWS OF COLLAPSED TUBES, NOS. 50-54, TAKEN WITH THE TUBES AT DIFFERENT ANGLES

SERIES ONE

This series of tests was made on tubes that were 8⅝ inches outside diameter, for all the different commercial thicknesses of wall, and in lengths of 2½, 5, 10, 15 and 20 feet between transverse joints tending to hold the tube to a circular form. The chief purpose of this series of tests was to furnish data for determining which of the existing formulæ, if any, were applicable to modern lap-welded steel tubes, especially when used in comparatively long lengths, such as well casing, boiler tubes and long plain flues.

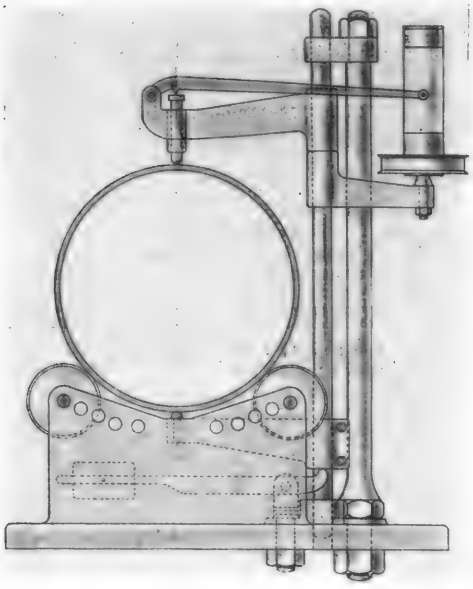
SERIES TWO

This series of tests was made on single lengths of 20 feet between end connection, tending to hold the tube to a circular form. Seven sizes, from 3 to 10 inches outside diameter, and in all the commercial thicknesses obtainable, have been tested to date. The chief purpose of these tests was to obtain, for commercial tubes, the manner in which the collapsing pressure of a tube is related to both the diameter and thickness of wall.

INAPPLICABILITY OF PREVIOUSLY PUBLISHED FORMULÆ

Preparatory to entering upon the present research all existing published formulæ that could be found were collected, and, after the completion of series one, were tested as to their applicability to modern steel tubes. Among the formulæ thus tested were two each by Fairbairn, Unwin, Wehage and Clark, and one each by Nystrom, Grashof, Love, Belpaire and the Board of Trade (British), all of which, with possibly two exceptions, appear to be based upon Fairbairn's classical experiments made more than a half century ago, upon tubes wholly unlike the modern product. Without exception, all

*Abstract of paper read at the Chattanooga (Tenn.) meeting of the American Society of Mechanical Engineers, May 1-4, 1906.



AUTOGRAPHIC CALIPERING APPARATUS, NO. 2, FOR OBTAINING THE OUT-OF-ROUNDNESS OF TUBES

of these formulæ, when thus tested, proved to be inapplicable to the wide range of conditions found in modern practice. As an illustration of this, the very first tube tested in connection with this research failed under a pressure that exceeded by about 300 per cent. that calculated by means of Fairbairn's formula.

RESULTS OF PRESENT RESEARCH

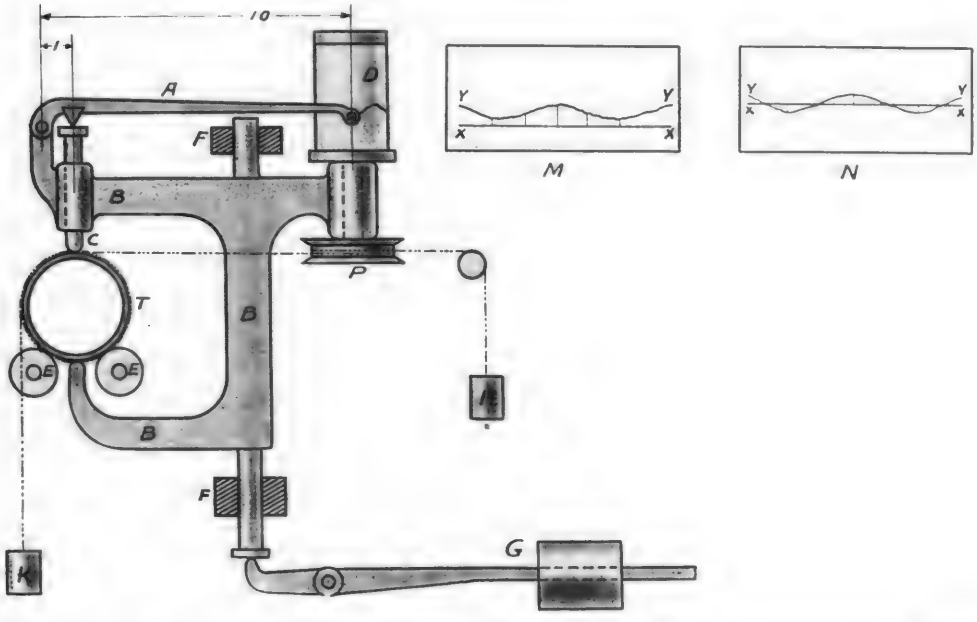
The principal conclusions to be drawn from the results of the present research may be briefly stated as follows:

1. The length of tube, between transverse joints tending to hold it to a circular form, has no practical influence upon the collapsing pressure of a commercial lap-welded steel tube so long as this length is not less than about six diameters of tube.

2. The formulæ, as based upon the present research, for the collapsing pressure of modern lap-welded Bessemer steel tubes, are as follows:

$$P = 1{,}000\left(1 - \sqrt{1 - 1{,}600\,\frac{2}{d^2}}\right). \quad . \quad (A)$$

$$P = 86.670\,\frac{t}{d} - 1{,}386 \quad . \quad . \quad . \quad . \quad . \quad (B)$$



The tube while being calipered is rotated on supporting guide wheels, one pair of which are shown at EE. By means of the guides FF, and the counter-balancing lever and weight G, the lower calipering point is constantly kept in contact with the tube while it is being made to rotate. Any variation in the vertical diameter of tube, while being rotated, will be indicated by the motion of the upper calipering point C, which variation is magnified ten fold and recorded on the drum D, by means of the pencil mechanism A.

The recording drum D, and the tube T are made to rotate synchronously by means of a cord weighted at both ends and passing once around both of them.

The curve YY is produced by one revolution of the tube, and XX by replacing the tube by a distance piece between the calipering points, equal to the nominal diameter of the tube being tested. The distance then between these lines, shows to scale the variation of actual from standard diameter for any given cross-section.

SKETCH SHOWING THE PRINCIPLE OF ACTION OF THE AUTOGRAPHIC CALIPERING APPARATUS, NO. 2

Where P = collapsing pressure, pounds per square inch.

d = outside diameter of tube in inches.

t = thickness of wall in inches.

Formula A is for values of P less than 581 pounds, or for values of $\frac{t}{d}$ less than 0.023, while formula B is for values greater than these.

These formulæ, while strictly correct for tubes that are 20 feet in length between transverse joints tending to hold them to a circular form, are, at the same time, substantially correct for all lengths greater than about six diameters. They have been tested for seven sizes, ranging from 3 to 10 inches outside diameter, in all obtainable commercial thicknesses of wall, and are known to be correct for this range.

For the convenience of those who wish to apply these formulæ to practice a table has been calculated (Figs. 1 and 2), giving the collapsing pressures of all the commercial sizes of lap-welded tubes from 2 to 11 inches outside diameter.

When applying these formulæ and tables to practice, it should be remembered that a suitable factor of safety must be applied.

3. The apparent fiber stress under which the different tubes failed varied from about 7,000 pounds for the relatively thinnest to 35,000 per square inch for the relatively thickest walls. Since the average yield point of the material was 37,000 and the tensile strength 58,000 pounds per square inch, it would appear that the strength of a tube subjected to a fluid collapsing pressure is not dependent alone upon either the elastic limit or ultimate strength of the material constituting it.

Preliminary Considerations

While planning this research it was assumed that the resistance offered by a tube to an external fluid pressure would depend upon the following five things, namely:

1. The diameter of the tube.
2. The length of tube between transverse joints or end connections tending to hold it to a circular form.
3. The thickness of the wall.
4. The deviation of the tube from perfect roundness.
5. The physical properties of the material of which the tube is made.

The only variations to be expected in Nos. 4 and 5 would be that due to the inability of the manufacturer to turn out a uniform product. It is recognized here that the physical properties of rolled steel depend in some measure, other things being equal, upon the thickness of the plate; or, in this case, upon the thickness of the wall of the tube. It is clear that any variation of this nature would be a function of the thickness, and would consequently be taken care of in an empirical formula by the quantity representing the thickness.

All the published formulæ bearing upon the subject indicated that the diameter and thickness of wall has each an important determining influence on the collapsing pressure of a tube, and since there were the best of theoretical reasons for believing this to be the case, it was, of course, decided to plan the research to discover, if possible, the precise nature of this influence over a wide commercial range.

The influence of length of tube, between transverse joints, or end connections tending to hold it to a circular form, upon the collapsing pressure, appeared, in the light of available data, to be the most uncertain of all the variables entering the problem. It was therefore decided, first of all, to determine the precise nature of this influence.

In order to do this the following apparatus was used, the greater part of which was especially constructed for this research:

HYDRAULIC TEST APPARATUS

The production of a suitable apparatus in which to subject the tubes to an external fluid pressure, and at the same time handle with expedition the large number of tests contemplated, was a somewhat difficult problem to solve. After much consideration of the matter the scheme illustrated was adopted. (Fig. 3.)

It will be seen by reference to this figure that the scheme provides for:

1. A test cylinder with one head removable for the reception of the tube to be tested, this cylinder being provided with means for creating an hydraulic pressure within, thus subjecting the tube under test to a fluid-collapsing pressure.
2. A low-pressure water supply of large volume to rapidly fill the space within the test cylinder not occupied by the tube under test.
3. A variable high-pressure water supply furnished by an hydraulic pressure pump, the purpose of which was to create a fluid pressure within the test cylinder, the tube under test by this means being subjected to a gradually increasing fluid-collapsing pressure.
4. A set of pressure gauges, having a large range in capacity, connected so that they could be used either singly for indicating the fluid pressure within the test cylinder or in combination for comparison.
5. A vent pipe leading from the interior of the tube under test through the head of the test cylinder to the atmosphere, in order to maintain constantly an atmospheric pressure within the tube being tested.
6. An air vent connecting with the highest point of the interior of the test cylinder, in order to thoroughly free from air the interior of the test cylinder, while being filled with water, after the insertion of a tube to be tested.

Probable Collapsing Pressures and Weights of National Tube Co's Lap-welded Bessemer Steel Tubes

The tabulated COLLAPSING PRESSURES (C. P.), in pounds per square inch fluid pressure, are calculated by formulas for 26 foot lengths, based upon experiments conducted by Prof. R. T. Stewart, 1902-04, and are substantially correct for lengths greater than 6 diameters.

The OUTSIDE DIAMETER (O.D.) of tube is in inches and the PLAIN END WEIGHT (Wt.) in pounds per foot length.

Calculated by E. E. 3 under direction of Prof. R. T. Stewart, 1905.

Note — Collapsing pressures calculated by formulas A & B. Weight of cubic inch steel = .2833 lbs.

Thickness of Wall Inches.	2" O.D.		2¼" O.D.		2½" O.D.		2¾" O.D.		3" O.D.		3⅛" O.D.		3½" O.D.		3¾" O.D.		4" O.D.		4⅛" O.D.		4½" O.D.		4¾" O.D.	
	Wt.	C.P.	Wt.	C.P.	Wt.	C.P.	Wt.	C.P.	Wt.	C.P.	Wt.	C.P.	Wt.	C.P.	Wt.	C.P.	Wt.	C.P.	Wt.	C.P.	Wt.	C.P.	Wt.	C.P.
0.10	2.03	2947	2.30	2466	2.56	2081	2.83	1766	3.10	1503	3.36	1281	3.63	1096	3.96	925	4.17	781	4.43	653	4.70	542	4.97	441
0.11	2.22	3381	2.51	2851	2.81	2427	3.10	2081	3.40	1792	3.69	1547	3.98	1339	4.28	1156	4.57	997	4.86	857	5.16	733	5.45	621
0.12	2.41	3814	2.73	3236	3.05	2774	3.37	2396	3.69	2081	4.01	1814	4.33	1586	4.65	1387	4.97	1214	5.29	1061	5.61	925	5.93	804
0.13	2.60	4248	2.94	3622	3.29	3121	3.64	2711	3.98	2370	4.33	2081	4.68	1833	5.03	1619	5.37	1431	5.72	1265	6.07	1118	6.41	986
0.14	2.78	4681	3.15	4007	3.53	3468	3.90	3026	4.28	2659	4.65	2347	5.02	2081	5.40	1850	5.77	1647	6.15	1469	6.52	1310	6.89	1168
0.15	2.96	5114	3.36	4392	3.76	3814	4.17	3341	4.57	2947	4.97	2614	5.37	2328	5.77	2081	6.17	1864	6.57	1673	6.97	1503	7.37	1351
0.16	3.14	5548	3.57	4777	4.00	4161	4.43	3657	4.85	3236	5.28	2881	5.71	2576	6.13	2312	6.54	2081	6.99	1877	7.42	1696	7.84	1533
0.17	3.32	5981	3.78	5162	4.23	4508	4.68	3972	5.14	3525	5.59	3148	6.05	2824	6.50	2543	6.95	2297	7.41	2081	7.86	1888	8.32	1714
0.18	3.50	6414	3.98	5548	4.46	4854	4.94	4287	5.42	3814	5.90	3414	6.38	3071	6.86	2774	7.34	2514	7.82	2285	8.30	2081	8.79	1898
0.19	3.67	6848	4.18	5933	4.69	5201	5.19	4602	5.70	4103	6.21	3681	6.72	3319	7.22	3005	7.73	2731	8.24	2489	8.75	2273	9.25	2081
0.20	3.84	7281	4.38	6318	4.91	5548	5.45	4917	5.98	4392	6.51	3948	7.05	3567	7.58	3236	8.12	2947	8.65	2693	9.18	2466	9.72	2263
0.21	4.01	7714	4.58	6703	5.14	5894	5.70	5232	6.26	4681	6.82	4214	7.38	3814	7.94	3468	8.50	3164	9.06	2897	9.62	2659	10.18	2446
0.22	4.18	8148	4.77	7088	5.36	6241	5.94	5548	6.53	4976	7.12	4481	7.71	4062	8.29	3699	8.88	3381	9.47	3100	10.06	2851	10.64	2628
0.23	4.35	8581	4.96	7474	5.58	6588	6.19	5863	6.80	5259	7.42	4748	8.03	4309	8.65	3930	9.26	3598	9.87	3304	10.49	3044	11.10	2811
0.24	4.51	9014	5.15	7859	5.79	6934	6.43	6178	7.07	5548	7.72	5014	8.36	4557	9.00	4161	9.64	3814	10.28	3508	10.92	3236	11.56	2993
0.25	4.67	9448	5.34	8244	6.01	7281	6.68	6493	7.34	5836	8.01	5281	8.68	4806	9.35	4392	10.01	4031	10.68	3712	11.35	3429	12.02	3176
0.26	4.83	9881	5.53	8629	6.22	7628	6.91	6808	7.61	6125	8.30	5548	9.00	5052	9.69	4623	10.39	4248	11.08	3916	11.77	3622	12.47	3357
0.27	—	—	5.71	9014	6.43	7974	7.15	7123	7.87	6414	8.59	5814	9.31	5300	10.04	4854	10.76	4464	11.48	4120	12.20	3814	12.92	3541
0.28	—	—	5.89	9460	6.64	8321	7.39	7439	8.13	6703	8.88	6081	9.63	5548	10.38	5085	11.12	4681	11.87	4324	12.62	4007	13.37	3723
0.29	—	—	6.07	9785	6.84	8668	7.62	7754	8.39	6992	9.17	6348	9.94	5795	10.72	5316	11.49	4898	12.27	4528	13.04	4199	13.81	3905
0.30	—	—	—	—	7.05	9014	7.85	9069	8.65	7281	9.45	6614	10.25	6043	11.05	5548	11.85	5114	12.66	4732	13.46	4392	14.26	4089
0.31	—	—	—	—	7.25	9341	8.08	9384	8.91	7576	9.73	6881	10.56	6290	11.39	5779	12.22	5331	13.04	4936	13.87	4585	14.70	4270
0.32	—	—	—	—	7.45	9708	8.30	8699	9.16	7859	10.01	7148	10.87	6538	11.72	6010	12.58	5548	13.43	5140	14.29	4777	15.14	4453
0.33	—	—	—	—	—	—	8.53	9014	9.41	8148	10.29	7414	11.17	6786	12.05	6241	12.93	5764	13.82	5344	14.70	4970	15.58	4635
0.34	—	—	—	—	—	—	8.75	9338	9.66	8437	10.57	7681	11.47	7033	12.38	6472	13.29	5981	14.20	5548	15.11	5162	16.01	4818
0.35	—	—	—	—	—	—	8.97	9645	9.91	8725	10.84	7948	11.77	7281	12.71	6703	13.64	6198	14.58	5752	15.51	5355	16.45	5000
0.36	—	—	—	—	—	—	9.19	9960	10.15	9014	11.11	8214	12.07	7529	13.03	6934	14.00	6414	14.96	5955	15.92	5548	16.88	5183
0.37	—	—	—	—	—	—	—	—	10.39	9303	11.38	8481	12.37	7774	13.36	7165	14.34	6631	15.33	6159	16.32	5740	17.31	5365
0.38	—	—	—	—	—	—	—	—	10.63	9592	11.65	8748	12.66	8024	13.68	7397	14.69	6848	15.71	6363	16.72	5933	17.79	5548
0.39	—	—	—	—	—	—	—	—	10.87	9881	11.91	9014	12.95	8272	14.00	7628	15.04	7064	16.09	6567	17.12	6125	18.16	5730
0.40	—	—	—	—	—	—	—	—	—	—	12.18	9281	13.24	8519	14.31	7859	15.38	7281	16.45	6771	17.52	6318	18.58	5913
0.41	—	—	—	—	—	—	—	—	—	—	12.44	9548	13.53	8767	14.63	8090	15.72	7498	16.81	6975	17.91	6511	19.00	6095
0.42	—	—	—	—	—	—	—	—	—	—	12.69	9814	13.82	9014	14.94	8321	16.06	7714	17.18	7179	18.30	6703	19.42	6273
0.43	—	—	—	—	—	—	—	—	—	—	—	—	14.10	9262	15.25	8552	16.46	7931	17.54	7383	18.69	6896	19.84	6450
0.44	—	—	—	—	—	—	—	—	—	—	—	—	14.38	9510	15.55	8784	16.73	8148	17.90	7587	19.08	7088	20.25	6628
0.45	—	—	—	—	—	—	—	—	—	—	—	—	14.66	9757	15.86	9014	17.06	8324	18.26	7791	19.46	7281	20.67	6805
0.46	—	—	—	—	—	—	—	—	—	—	—	—	—	—	16.16	9246	17.39	8581	18.62	7995	19.85	7474	21.08	7007
0.47	—	—	—	—	—	—	—	—	—	—	—	—	—	—	16.46	9477	17.72	8798	18.97	8199	20.23	7666	21.48	7190
0.48	—	—	—	—	—	—	—	—	—	—	—	—	—	—	16.76	9708	18.05	9014	19.33	8403	20.61	7859	21.89	7372
0.49	—	—	—	—	—	—	—	—	—	—	—	—	—	—	17.06	9939	18.37	9231	19.68	8607	20.99	8051	22.29	7555
0.50	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	18.69	9448	20.03	8810	21.36	8244	22.70	7737

FIG. 1. TABLE GIVING THE COLLAPSING PRESSURES OF ALL THE COMMERCIAL SIZES OF LAP-WELDED TUBES FROM 2 TO 4¾ INCHES, OUTSIDE DIAMETER

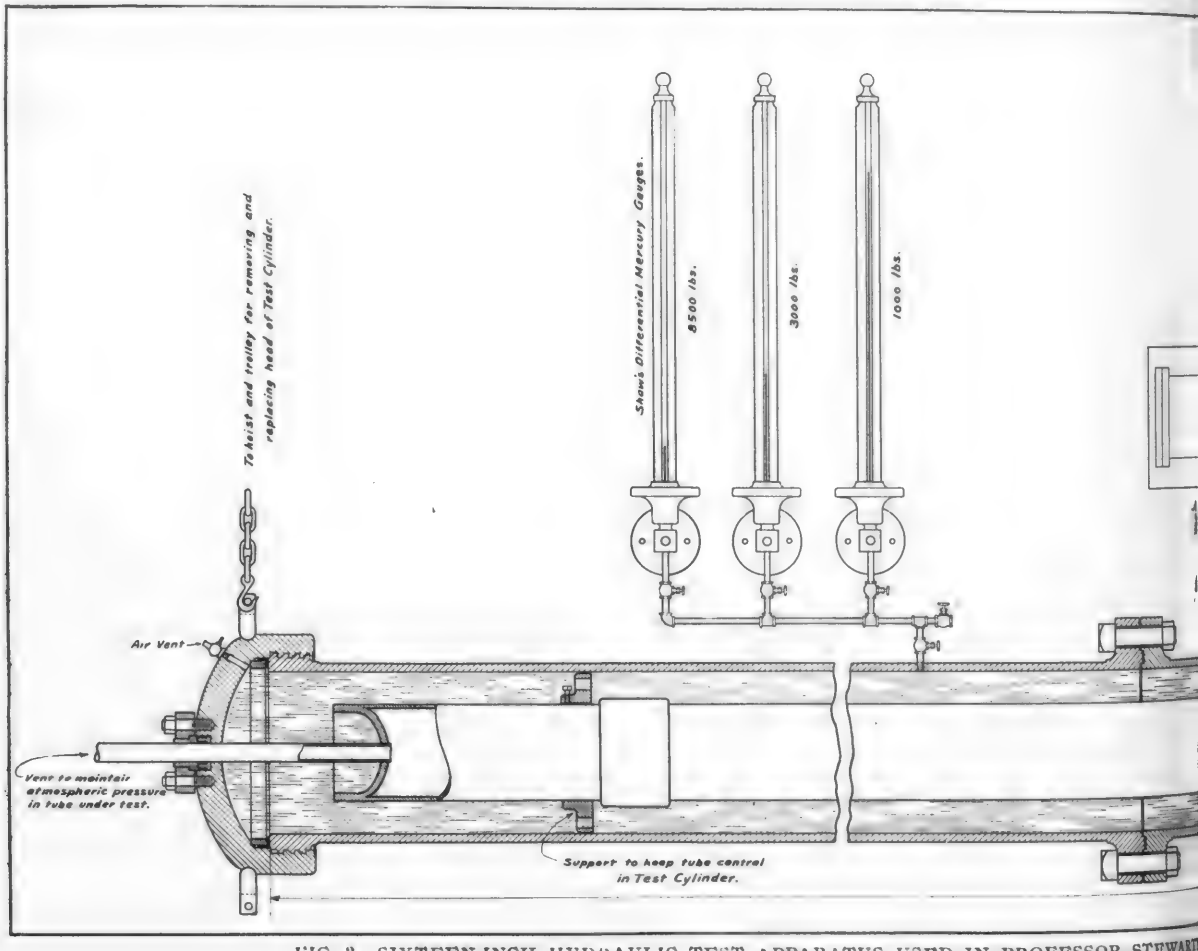

To hoist and trolley for removing and replacing head of Test Cylinder.
Shaw's Differential Mercury Gauges.
8500 lbs.
3000 lbs.
1000 lbs.
Air Vent
Vent to maintain atmospheric pressure in tube under test.
Support to keep tube central in Test Cylinder.

FIG. 3. SIXTEEN-INCH HYDRAULIC TEST APPARATUS USED IN PROFESSOR STEWART

Probable Collapsing Pressures and Weights of National Tube Co's Lap-welded Bessemer Steel Tubes.

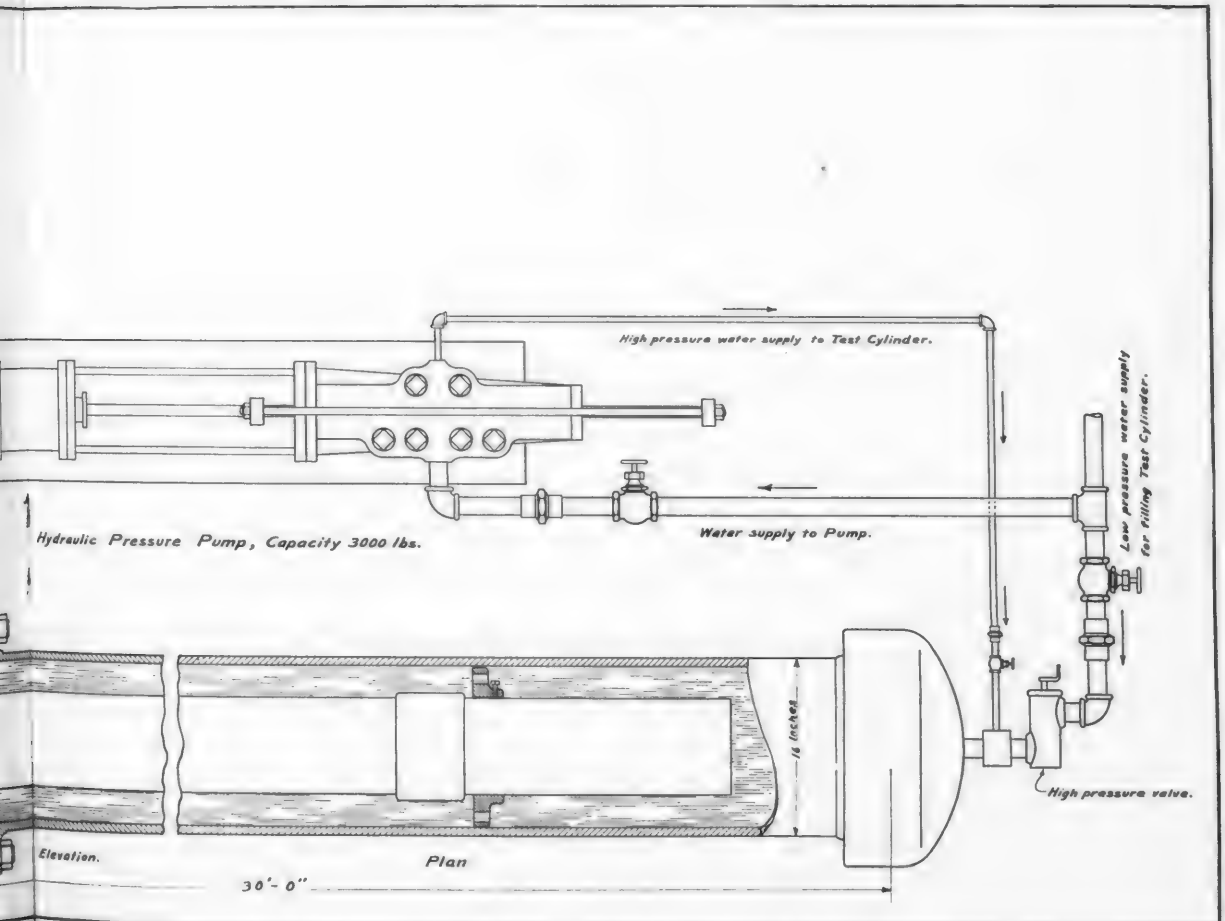
The tabulated COLLAPSING PRESSURES (C.P.) in pounds per square inch fluid pressure, are calculated by formulas for 20 foot lengths, based upon experiments conducted by Prof. R.T. Stewart, 1902-04, and are substantially correct for lengths greater than 6 diameters.

The OUTSIDE DIAMETER (O.D.) of tube is in inches and the PLAIN END WEIGHT (Wt.) in pounds per foot length.

Calculated by E.E.S. under direction of Prof. R.T. Stewart, 1908.

Thickness of Wall Inches.	5" O.D.		5 1/16 O.D.		5 1/8 O.D.		6" O.D.		6 1/16 O.D.		7" O.D.		7 1/8" O.D.		8" O.D.		8 1/8 O.D.		9" O.D.		10" O.D.		11" O.D.	
	Wt.	C.P.	Wt.	C.P.	Wt.	C.P.	Wt.	C.P.	Wt.	C.P.	Wt.	C.P.	Wt.	C.P.	Wt.	C.P.	Wt.	C.P.	Wt.	C.P.	Wt.	C.P.	Wt.	C.P.
0.10																								
0.11	5.74	525	6.04	454	6.33	400																		
0.12	6.25	654	6.57	595	6.90	512	7.54	400	8.34	311														
0.13	6.76	867	7.11	760	7.46	663	8.15	501	9.02	390	9.54	331	10.41	269	10.93	240								
0.14	7.27	1041	7.64	925	8.01	820	8.76	636	9.70	466	10.26	400	11.19	321	11.75	284	12.69	237	13.25	217				
0.15	7.77	1214	8.17	1090	8.57	978	9.37	781	10.37	576	10.97	485	11.98	383	12.58	339	13.58	282	14.18	255	15.78	206		
0.16	8.27	1387	8.70	1255	9.13	1135	9.98	925	11.05	707	11.69	595	12.76	456	13.40	400	14.47	330	15.11	297	16.81	232	19.52	187
0.17	8.77	1561	9.22	1420	9.68	1293	10.59	1078	11.72	838	12.40	719	13.54	548	14.22	473	15.35	385	16.03	345	17.85	267	19.66	214
0.18	9.27	1734	9.75	1586	10.23	1456	11.19	1214	12.39	969	13.11	843	14.31	660	15.03	564	16.23	449	16.96	400	18.88	306	20.80	244
0.19	9.76	1907	10.27	1751	10.78	1608	11.79	1359	13.06	1160	13.82	966	15.09	774	15.85	672	17.12	527	17.88	464	19.91	350	21.94	277
0.20	10.25	2081	10.79	1916	11.32	1766	12.39	1503	13.72	1230	14.53	1090	15.96	897	16.66	781	18.06	624	18.80	542	20.93	400	23.07	314
0.21	10.74	2254	11.30	2081	11.86	1923	12.99	1647	14.39	1361	15.23	1214	16.63	1001	17.47	889	18.87	724	19.71	636	21.96	457	24.20	354
0.22	11.23	2427	11.82	2246	12.41	2081	13.58	1792	15.05	1492	15.93	1338	17.46	1115	18.28	997	19.75	826	20.63	733	22.98	525	25.33	406
0.23	11.72	2601	12.33	2411	12.95	2238	14.17	1936	15.71	1623	16.63	1462	18.17	1228	19.09	1106	20.62	925	21.54	829	24.00	607	26.46	452
0.24	12.20	2774	12.84	2576	13.48	2396	14.76	2081	16.37	1754	17.33	1586	18.93	1342	19.89	1214	21.49	1026	22.45	925	25.02	694	27.58	512
0.25	12.68	2947	13.35	2741	14.02	2554	15.35	2225	17.02	1885	18.02	1709	19.69	1456	20.69	1322	22.36	1126	23.36	1022	26.03	781	28.76	584
0.26	13.16	3121	13.86	2906	14.55	2711	15.94	2370	17.67	2015	18.72	1833	20.45	1569	21.49	1431	23.23	1227	24.27	1118	27.05	867	29.82	663
0.27	13.64	3294	14.36	3071	15.08	2869	16.52	2514	18.33	2146	19.41	1957	21.21	1683	22.29	1539	24.09	1327	25.17	1214	28.06	954	30.94	741
0.28	14.11	3468	14.86	3236	15.61	3026	17.11	2659	18.99	2277	20.10	2081	21.96	1797	23.09	1647	24.96	1428	26.08	1310	29.07	1041	32.06	820
0.29	14.59	3641	15.36	3401	16.14	3184	17.69	2803	19.62	2408	20.78	2205	22.72	1910	23.88	1756	25.82	1528	26.98	1407	30.07	1127	33.17	899
0.30	15.06	3814	15.86	3567	16.66	3341	18.26	2947	20.27	2539	21.47	2328	23.47	2024	24.67	1824	26.67	1629	27.88	1503	31.08	1214	34.28	978
0.31	15.53	3988	16.36	3732	17.18	3499	18.84	3092	20.91	2670	22.15	2452	24.22	2138	25.46	1972	27.53	1729	28.77	1599	32.08	1301	35.39	1057
0.32	15.99	4161	16.85	3897	17.70	3657	19.41	3236	21.55	2800	22.83	2576	24.97	2251	26.25	2081	28.38	1830	29.67	1696	33.08	1387	36.50	1135
0.33	16.46	4334	17.34	4062	18.22	3814	19.98	3381	22.19	2931	23.51	2766	25.71	2365	27.03	2189	29.24	1930	30.56	1792	34.08	1474	37.61	1214
0.34	16.92	4508	17.83	4227	18.74	3972	20.55	3525	22.82	3062	24.19	2824	26.45	2479	27.82	2297	30.08	2031	31.45	1888	35.08	1561	38.71	1293
0.35	17.38	4681	18.32	4392	19.25	4129	21.12	3670	23.46	3193	24.86	2947	27.19	2592	28.60	2406	30.93	2131	32.33	1985	36.07	1647	39.81	1372
0.36	17.84	4854	18.80	4557	19.76	4287	21.68	3814	24.09	3324	25.53	3071	27.93	2706	29.37	2514	31.78	2232	33.22	2081	37.06	1734	40.91	1458
0.37	18.30	5028	19.28	4722	20.27	4445	22.25	3959	24.72	3454	26.20	3195	28.67	2826	30.15	2632	32.62	2332	34.10	2177	38.05	1824	42.01	1529
0.38	18.75	5201	19.76	4887	20.78	4602	22.81	4103	25.35	3585	26.87	3319	29.40	2933	30.93	2731	33.46	2433	34.98	2273	39.04	1907	43.10	1608
0.39	19.20	5374	20.24	5052	21.28	4760	23.37	4248	25.97	3716	27.53	3445	30.14	3047	31.70	2839	34.30	2533	35.86	2370	40.03	1994	44.19	1687
0.40	19.65	5548	20.72	5217	21.79	4917	23.92	4392	26.59	3847	28.20	3567	30.87	3161	32.47	2947	35.14	2633	36.74	2466	41.01	2081	45.28	1766
0.41	20.10	5721	21.19	5383	22.29	5075	24.48	4536	27.21	3978	28.86	3690	31.59	3274	33.24	3056	35.97	2734	37.61	2562	41.99	2167	46.37	1844
0.42	20.54	5894	21.67	5548	22.79	5232	25.03	4681	27.83	4109	29.52	3814	32.32	3388	34.00	3164	36.80	2839	38.49	2659	42.97	2254	47.46	1923
0.43	20.99	6068	22.14	5713	23.28	5390	25.58	4825	28.45	4239	30.17	3938	33.04	3502	34.76	3273	37.64	2935	39.36	2755	43.95	2341	48.54	2002
0.44	21.43	6241	22.60	5878	23.78	5548	26.13	4970	29.06	4370	30.83	4062	33.76	3615	35.53	3381	38.46	3035	40.23	2851	44.93	2427	49.62	2081
0.45	21.87	6414	23.07	6043	24.27	5705	26.67	5114	29.68	4501	31.48	4186	34.48	3729	36.29	3489	39.29	3136	41.09	2947	45.90	2514	50.70	2160
0.46	22.30	6588	23.53	6208	24.76	5863	27.22	5259	30.29	4632	32.13	4309	35.20	3843	37.04	3598	40.11	3236	41.96	3044	46.87	2601	51.78	2238
0.47	22.74	6761	23.99	6373	25.25	6020	27.76	5403	30.90	4763	32.78	4433	35.92	3956	37.80	3706	40.94	3337	42.82	3140	47.84	2687	52.86	2317
0.48	23.17	6934	24.45	6538	25.73	6178	28.30	5548	31.50	4893	33.42	4557	36.63	4070	38.55	3814	41.76	3437	43.68	3236	48.86	2774	53.95	2396
0.49	23.60	7108	24.91	6703	26.22	6336	28.84	5692	32.11	5024	34.07	4681	37.34	4184	39.30	3923	42.57	3538	44.54	3333	49.77	2861	55.00	2475
0.50	24.03	7281	25.37	6869	26.70	6493	29.37	5837	32.71	5155	34.71	4805	38.05	4297	40.05	4031	43.39	3638	45.39	3429	50.73	2947	56.07	2554

FIG. 2. TABLE GIVING THE COLLAPSING PRESSURES OF ALL THE COMMERCIAL SIZES OF LAP-WELDED TUBES FROM 5 TO 11 INCHES. OUTSIDE DIAMETER



WARTS TESTS OF THE COLLAPSING PRESSURES OF BESSEMER STEEL LAP-WELDED TUBES

HYDRAULIC PRESSURE PUMP

The pressure within the test cylinder was created by means of an hydraulic pressure pump capable of working against a fluid pressure up to 3,000 pounds per square inch. Ordinarily this pump was operated, upon entering the region of expected collapse, so as to increase the fluid pressure at a rate of from about 2 to 10 pounds per second, depending upon the gauge used. At these rates of increase of pressure the conditions were favorable for the making of an exact determination of the fluid pressure under which the tube failed.

EIGHT-INCH TEST CYLINDER

This smaller cylinder was constructed for the purpose of testing the 3 and 4 inch tubes, and nearly all of these sizes were tested in it. This test cylinder was made up from a single 20 foot length of 8 inch double extra strong pipe, 8⅝ inches outside diameter, and ⅞ inch wall.

The details of one end of this cylinder, with tube under test in place, are shown in Figs. 4-7, the other end being an exact duplicate of the one shown. It will be observed that this apparatus is arranged so as to permit of testing a plain end tube, with the ends open to the atmosphere and the interior of the tube exposed to view while under test. In this way the tube while under test is entirely relieved of any longitudinal stress due to the fluid pressure surrounding it. The sectional view shows clearly the construction of the cylinder.

TESTS HEADS, SUPPORTS AND VENTS

The different styles of test heads used, the manner of supporting the tube in the test cylinder and the vent pipes connecting the interior of the tube under test with the atmosphere, are clearly shown in Figs. 4-7.

Collapsing Tests, Series One, Showing the Influence of Length of Tube on the Collapsing Pressure

Since the influence of the length of tube, between transverse joints or end connection tending to hold it to a circular form, upon the collapsing pressure appeared to be the most uncertain element entering the problem, it was thought best, first of all, to determine the precise nature of this influence. Accordingly, it was decided to make a series of tests on a single diameter of tube for all the commercial thicknesses of wall obtainable, in five different lengths of from 2½ to 20 feet.

DIAMETER OF TUBE TESTED

For Series One it was decided to use 8¼ inch well casing, which has a nominal outside diameter of 8⅝ inches. This size was adopted because, taking all things into consideration, it seemed to afford the greatest oportunities for getting at the results desired.

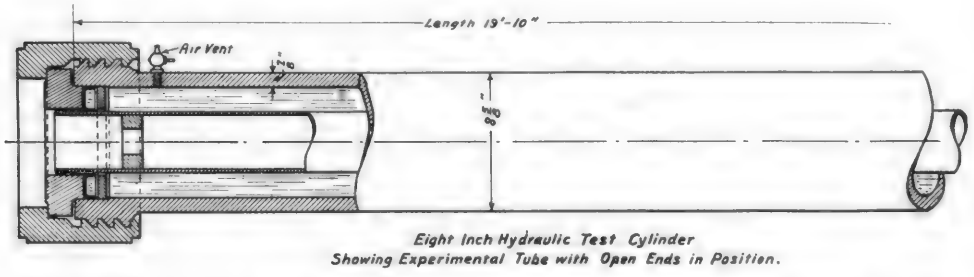


FIG. 4. EIGHT-INCH HYDRAULIC TEST CYLINDER, SHOWING EXPERIMENTAL TUBE WITH OPEN ENDS IN POSITION

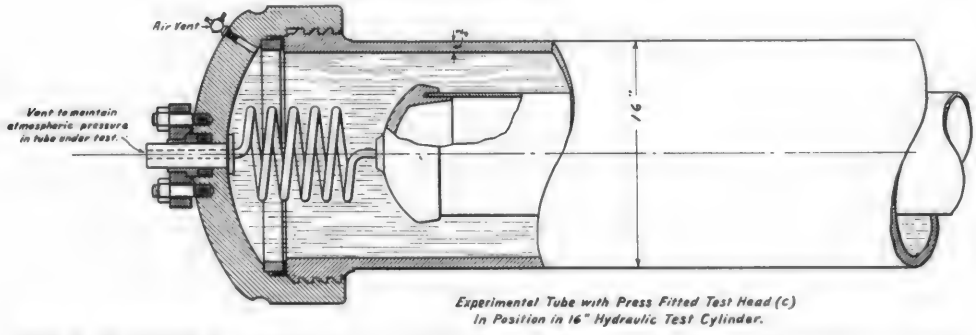

Air Vent
Vent to maintain atmospheric pressure in tube under test.
16"
Experimental Tube with Press Fitted Test Head (c)
In Position in 16" Hydraulic Test Cylinder.

FIG. 5. SIXTEEN-INCH HYDRAULIC TEST CYLINDER, SHOWING EXPERIMENTAL TUBE WITH PRESS FITTED TEST HEAD (C) IN POSITION

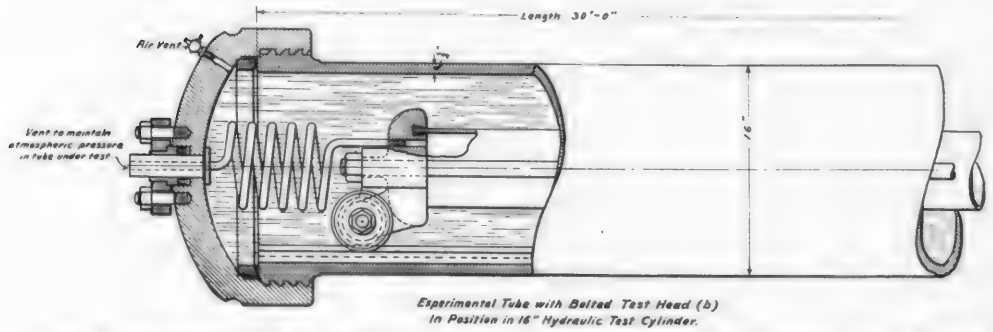

Length 30'-0"
Air Vent
Vent to maintain atmospheric pressure in tube under test
16"
Experimental Tube with Bolted Test Head (b) In Position in 16" Hydraulic Test Cylinder.

FIG 6. SIXTEEN-INCH HYDRAULIC TEST CYLINDER, SHOWING EXPERIMENTAL TUBE WITH BOLTED TEST HEAD (B) IN POSITION

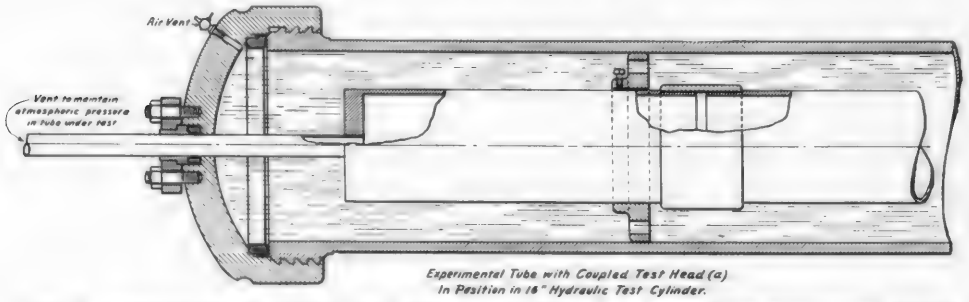

Air Vent
Vent to maintain atmospheric pressure in tube under test
Experimental Tube with Coupled Test Head (a) In Position in 16" Hydraulic Test Cylinder.

FIG. 7. SIXTEEN-INCH HYDRAULIC TEST CYLINDER, SHOWING EXPERIMENTAL TUBE WITH COUPLED TEST HEAD (A) IN POSITION

DEDUCTION OF LAW SHOWING THE RELATION OF COLLAPSING PRESSURE TO THE LENGTH OF TUBE

In order to arrive at the law expressing the collapsing pressure in terms of the length of tube and the different thicknesses of wall, for the diameter chosen, it was necessary, first of all, to arrange the tests of Series One in the manner shown (Figs. 8, 9 and 10).

It will be observed that the tests have been grouped so that, for each of the five lengths of tubes tested, the actual average thickness of wall for each experimental tube shall fall in the group having the nearest nominal thickness of wall.

COLLAPSING PRESSURE CORRECTED TO NOMINAL THICKNESS

In the seventh column, or the first of those headed "Collapsing Pressure," are entered the observed collapsing pressures. These pressures, of course, in each case correspond to the actual thickness of the tube. Since the actual thicknesses of different commercial tubes of the same nominal thickness of wall vary somewhat in practice, as is evident from running the eye down column 4 of this table, it became necessary, in order to get strictly comparable results, to obtain from the observed collapsing pressure of each experimental tube, whose thickness of wall did not equal exactly the nominal thickness, a collapsing pressure that would correspond to this nominal thickness. That is to say, the observed collapsing pressures corresponding to the respective thicknesses of wall tested were corrected, so that each would represent what the collapsing pressure would have been had the tube had the exact nominal thickness instead of that tabulated in column 4. These collapsing pressures, having been thus corrected to correspond to the nominal thickness of wall, are entered in column 8, or the second of those headed "Collapsing Pressure."

This correction was made graphically (Fig. 11) by first plotting, to a vertical scale representing collapsing pressure and a horizontal scale representing thickness of wall, the results of the tests for all the different thicknesses of wall for each of the five lengths of tube; second, drawing the mean line representing average results; and, third, drawing a line parallel to this mean line through the plotted value for each tube intersecting the ordinate corresponding to the thickness of that tube. The collapsing pressure corresponding to this point of intersection was then read and recorded in column 8.

RELATION OF COLLAPSING PRESSURE TO LENGTH OF TUBE

This relation is clearly shown on Fig. 11 for 8¼ inch casing (8⅝ inches outside diameter) in the four nominal thicknesses of 0.180, 0.229, 0.271, 0.322 inch and for lengths of from 2 to 20 feet between the regular screwed couplings.

On this chart the combined circles and crosses represent the different plotted

EFFECT OF LENGTH ON COLLAPSING PRESSURE.— Abstract from Log of Tests Conducted by Prof. R.T. Stewart, 1902-04, on National Tube Co.'s Lap-welded Bessemer Steel Tubes in Lengths of 2½, 5, 10, 15, and 20 Feet, 8⅝" Outside Diameter, to Determine the Effect of Length of Tube on the Collapsing Pressure; to which is Added a Comparison with Values Read from the Curve, M, Representing the Average Results of these Tests. Made by E.E.S. under direction of R.T.S. 1905.

Tests Grouped and Arranged in Order of Length and Thickness of Tube.

Number of Test.	Actual Outside Diameter, Inches.	Thickness of Wall, Inches. Nominal	Thickness of Wall, Inches. Computed from Wgt.	Unsupported Length of Tube. Feet.	Actual Plain End Weight, Lbs. per Ft	Collapsing Pressure Pounds per Square Inch. Observed	Collapsing Pressure Pounds per Square Inch. Corrected to Nom. Thk.	Collapsing Pressure Pounds per Square Inch. From Curve M.	Collapsing Pressure Pounds per Square Inch. % Variation from M.	Designation of Tube, as Reported
22	8.657		0.168	2.213	15.23	815	940		- 3	
24	8.655		0.170	2.212	15.41	1085	1185		+22	2½ Foot Lengths.
23	8.649	0.180	0.181	2.220	16.41	1085	1075	970	+11	
25	8.661		0.181	2.205	16.93	985	965		- 0.5	8¼" Casing, 16.07 lbs.
21	8.658		0.182	2.198.	16.45	915	895		- 7.5	
Average	8.656		0.176	2.210	15.99	977	1012		+ 4.4	
19	8.665		0.173	4.718	15.64	525	605		+ 6	
18	8.661		0.180	4.702	16.34	540	540		- 5	5 Foot Lengths.
17	8.659	0.180	0.181	4.708	16.42	575	565	570	- 1	
16	8.650		0.182	4.688	16.43	615	590		+ 3.5	8¼" Casing, 16.07 lbs.
20	8.654		0.182	4.703	16.43	705	685		+20	
Average	8.658		0.180	4.704	16.25	592	597		+ 4.7	
14	8.649		0.171	9.695	15.51	455	555		+ 6	
13	8.666		0.177	9.695	16.03	590	625		+19	10 Foot Lengths.
15	8.651	0.180	0.178	9.705	16.11	550	575	525	+ 9.5	
12	8.654		0.180	9.691	16.26	570	570		+ 8.5	8¼" Casing, 16.07 lbs.
11	8.662		0.184	9.715	16.65	575	535		+ 2	
30	8.670	0.229	0.197	11.950	17.79	650	465	520	- 10.5	8¼" Casing, 20.10 lbs.
Average	8.659		0.181	10.075	16.39	565	554		+ 5.7	
7	8.651		0.174	14.723	15.76	425	490		- 2	
8	8.655		0.183	14.762	16.54	550	520		+ 4	15 Foot Lengths.
6	8.651	0.180	0.186	14.708	16.82	575	510	500	+ 2	
10	8.652		0.188	14.700	16.95	580	495		- 1	8¼" Casing, 16.07 lbs.
9	8.655		0.191	14.708	17.21	610	495		- 1	
Average	8.653		0.184	14.708	16.66	548	502		+ 0.4	
1	8.657		0.176	19.818	15.92	450	490		+ 3	
4	8.640		0.183	19.702	16.54	450	420		-11.5	20 Foot Lengths.
3	8.641	0.180	0.186	19.695	16.77	535	475	475	0	
2	8.637		0.191	19.696	17.24	625	515		+ 8.5	8¼" Casing, 16.07 lbs.
5	8.638		0.191	19.709	17.23	620	505		+ 6.5	
Average	8.643		0.185	19.724	16.74	536	481		+ 1.3	
45	8.650		0.210	2.188	18.93	1240	1435		- 1	
48	8.677		0.210	2.206	19.02	1353	1545		+ 6.5	2½ Foot Lengths.
49	8.655	0.229	0.212	2.218	19.10	1305	1480	1450	+ 2	
46	8.648		0.213	2.226	19.18	1330	1495		+ 3	8¼" Casing, 20.10 lbs.
47	8.657		0.214	2.193	19.26	1340	1495		+ 3	
Average	8.657		0.212	2.205	19.10	1314	1490		+ 2.7	
44	8.664		0.207	4.711	18.66	910	1165		+ 2	
41	8.653		0.208	4.686	18.74	970	1215		+ 6	5 Foot Lengths.
42	8.670	0.229	0.210	4.687	18.93	805	1030	1145	-10	
40	8.657		0.216	4.713	19.48	975	1125		- 2	8¼" Casing, 20.10 lbs.
43	8.661		0.219	4.686	19.72	875	995		-13	
Average	8.661		0.212	4.695	19.11	907	1106		- 3.4	
38	8.666		0.208	9.716	18.77	700	930	1075	-13.5	
32	8.660		0.209	11.451	18.86	730	958	1055	-10	
31	8.658		0.210	11.816	18.96	810	1020	1050	- 3	
35	8.665		0.212	9.701	19.17	880	1070	1075	- 0.5	10 Foot Lengths
36	8.663	0.229	0.215	9.702	19.34	842	1000	"	- 7.	
39	8.688		0.217	9.705	19.59	845	980	"	- 9	8¼" Casing, 20.10 lbs.
37	8.665		0.220	9.701	19.82	960	1060	"	- 1.5	
33	8.664		0.226	11.364	20.38	840	975	1055	-17	
34	8.669		0.232	11.366	20.89	960	925	"	-12.5	
Average	8.666		0.217	10.502	19.52	841	979		-8.2	
1	2	3	4	5	6	7	8	9	10	11

Note:- To obtain collapsing pressures for curve N, multiply corresponding tabular collapsing pressures from curve M by 0.944. Curve M is based upon Series One only, while curve N is based jointly upon both Series One and Series Two.

FIG. 8. ARRANGEMENT OF TESTS IN SERIES ONE

EFFECT OF LENGTH ON COLLAPSING PRESSURE.— Abstract from Log of Tests Conducted by Prof. R.T. Stewart, 1902-04, on National Tube Co.'s. Lap-welded Bessemer Steel Tubes in Lengths of 2½, 5, 10, 15, and 20 Feet, 8⅝" Outside Diameter, to Determine the Effect of Length of Tube on the Collapsing Pressure; to which is Added a Comparison with Values Read from the Curve, M, Representing the Average Results of these Tests. Made by E.E.S. under direction of R.T.S., 1905.

Tests Grouped and Arranged in Order of Length and Thickness of Tube.

Number of Test.	Actual Outside Diameter Inches.	Thickness of Wall, Inches. Nominal	Thickness of Wall, Inches. Computed from Wgt.	Unsupported Length of Tube Feet.	Actual Plain End Weight, Lbs per Ft.	Collapsing Pressure. Pounds per Square Inch. Observed	Corrected to Nom. Thk.	From Curve M.	% Variation from M.	Designation of Tube, as Reported
28	8.659		0.213	12.630	19.23	850	1015		- 2.5	
29	8.650	0.229	0.213	12.372	19.16	750	915	1040	-12.5	15 Foot Lengths.
27	8.628		0.233	13.373	20.95	1115	1075		- 4	8¼" Casing, 20.10 lbs.
Average	8.646		0.220	12.792	19.78	965	1002		- 6.3	
26	8.604	0.229	0.219	18.866	19.57	870	970	980	- 1	20 Foot Lengths 8¼" Casing, 20.10 lbs.
70	8.673	0.271	0.253	2.147	22.72	1475	1675		-13.5	8¼" Casing, 24.38 lbs.
93	8.657	0.281	0.259	2.156	23.23	1985	2125		+ 11	8" Line Pipe, 25.66 lbs.
97	8.675	0.281	0.261	2.151	23.45	1915	2030		+ 12	" " " " "
96	8.656	0.281	0.268	2.146	24.00	1940	1975		+ 2	" " " " "
73	8.680	0.271	0.269	2.136	24.15	1850	1870	1935	- 3	8¼" Casing, 24.38 lbs.
71	8.650	0.271	0.271	2.146	24.20	1930	1930		0	" " " "
72	8.662	0.271	0.273	2.026	24.47	1880	1855		- 5	" " " "
74	8.644	0.271	0.274	2.146	24.50	1785	1750		- 9.5	" " " "
95	8.648	0.281	0.278	2.154	24.92	1765	1685		-13	8" Line Pipe, 25.16 lbs.
94	8.638	0.281	0.279	2.146	24.90	2200	2110		+ 9.5	" " " " "
Average	8.658		0.268	2.135	24.04	1872	1900		- 1.0	2½ Foot Lengths. Corrected to Nom. Thk. 0.271
68	8.648	0.271	0.257	4.638	22.99	1345	1510		- 9	8¼" Casing, 24.38 lbs.
66	8.653	0.271	0.268	4.641	23.97	1520	1560		- 6	" " " "
69	8.670	0.271	0.268	4.651	24.02	1925	1965		+ 8	" " " "
67	8.651	0.271	0.269	4.641	24.07	1640	1670		+ 0.5	" " " "
92	8.674	0.281	0.273	4.646	24.50	2030	2005	1665	+21	8" Line Pipe, 25.16 lbs.
91	8.664	0.281	0.275	4.644	24.61	1625	1570		- 5.5	" " " "
65	8.656	0.271	0.277	4.626	24.86	1750	1695		+ 1	8¼" Casing, 24.38 lbs.
88	8.651	0.281	0.279	4.641	24.93	1615	1525		- 8.5	8" Line Pipe, 25.16 lbs.
90	8.685	0.281	0.284	4.646	25.45	1700	1550		- 7	" " " " "
89	8.684	0.281	0.287	4.636	25.75	1685	1495		-10	" " " " "
Average	8.664		0.274	4.641	24.51	1684	1653		- 1.5	5 Foot Lengths Corrected to Nom. Thk. 0.271.
85	8.644	0.281	0.260	9.646	23.28	1575	1695		+ 9.5	8" Line Pipe, 25.16 lbs.
64	8.657	0.271	0.260	9.666	23.28	1450	1570		+ 1.5	8¼" Casing, 24.38 lbs.
61	8.668	0.271	0.265	9.656	23.75	1150	1215		-21.5	" " " "
63	8.662	0.271	0.267	9.641	23.94	1585	1625		+ 5	" " " "
62	8.679	0.271	0.268	9.636	24.05	1628	1660		+ 7	" " " "
83	8.669	0.281	0.270	9.658	24.20	1440	1450	1550	- 6.5	8" Line Pipe, 25.16 lbs.
87	8.664	0.281	0.272	9.656	24.40	1645	1635		+ 5.5	" " " " "
84	8.695	0.281	0.275	9.648	24.72	1500	1460		- 6	" " " " "
60	8.673	0.271	0.276	9.596	24.75	1850	1795		+16	8¼" Casing, 24.38 lbs.
86	8.663	0.281	0.278	9.636	24.85	1545	1470		- 5	8" Line Pipe, 25.16 lbs.
111	8.642	0.322	0.287	9.636	25.58	1725	1550		0	" " " " "
109	8.652	0.322	0.291	9.640	24.60	1905	1685		+ 9	" " " " "
Average	8.666		0.272	9.642	24.40	1583	1547		+ 1.2	10 Foot Lengths. Corrected to Nom. Thk. 0.271.
57	8.645	0.271	0.263	14.656	23.54	1590	1675		+13.5	8¼" Casing, 24.38 lbs.
124	8.644	0.281	0.263	14.641	23.56	1250	1335		- 9.5	8" Line Pipe, 25.16 lbs.
*79	8.664	0.281	0.266	17.986	23.84	1425	1480	——	——	" " " " "
98	8.656	0.281	0.266	14.646	23.85	1385	1440		- 2.5	" " " " "
82	8.662	0.281	0.271	14.636	24.27	1490	1490		+ 1	" " " " "
59	8.662	0.271	0.272	14.614	24.33	1710	1700	1475	+15	8¼" Casing, 24.38 lbs
55	8.648	0.271	0.273	14.636	24.35	1590	1565		+ 6	" " " "
56	8.650	0.271	0.275	14.646	24.55	1428	1380		- 6.5	" " " "
81	8.666	0.281	0.276	14.641	24.73	1365	1255		-15	8" Line Pipe, 25.16 lbs.
58	8.665	0.271	0.278	14.656	24.87	1390	1315		-11	8¼" Casing, 24.38 lbs.
104	8.645	0.322	0.296	14.630	25.88	1725	1525		+ 3.5	8" Line Pipe, 28.18 lbs.
Average	8.653		0.273	14.640	24.39	1485	1448		- 0.5	15' Lengths, to Nom. Thk. 0.271 * See 20 Foot Lengths.
1	2	3	4	5	6	7	8	9	10	11

FIG. 9. ARRANGEMENT OF TESTS IN SERIES ONE

EFFECT OF LENGTH ON COLLAPSING PRESSURE.— Abstract from Log of Tests Conducted by Prof. R.T. Stewart, 1902-04, on National Tube Co.'s Lap-welded Bessemer Steel Tubes in Lengths of 2½, 5, 10, 15, and 20 Feet, 8⅝" Outside Diameter, to Determine the Effect of Length of Tube on the Collapsing Pressure, to which is Added a Comparison with Values Read from the Curve, M, Representing the Average Results of these Tests. Made by E.E.S. under direction of R.T.S., 1905.

Tests Grouped and Arranged in Order of Length and Thickness of Tubes.

Number of Test	Actual Outside Diameter, Inches	Thickness of Wall, Inches: Nominal	Thickness of Wall, Inches: Computed from Wgt.	Unsupported Length of Tube, Feet.	Actual Plain End Weight, Lbs. per Ft.	Collapsing Pressure, Pounds per Square Inch.: Observed	Corrected to Nom. Thk.	From Curve M	% Variation from M.	Designation of Tube, as Reported.
52	8.664	0.271	0.258	19.649	23.13	1320	1450		+ 2	8¼" Casing, 24.38 lbs.
54	8.660	0.271	0.262	19.639	23.52	1485	1580		+11.5	" " " "
99	8.663	0.322	0.264	19.646	23.66	1375	1450		+ 2	8" Line Pipe, 28.18 lbs.
*79	8.664	0.281	0.266	17.986	23.84	1425	1480		+ 2.5	" " " 25.00 lbs.
50	8.666	0.271	0.271	19.646	24.28	1435	1435		+ 1	8¼" Casing, 24.38 lbs.
53	8.660	0.271	0.272	19.638	24.32	1520	1510	1420	+ 6.5	" " " 1h
76	8.663	0.281	0.272	19.634	24.38	1410	1400		- 1.5	8" Line Pipe, 25.00 lbs.
51	8.668	0.271	0.274	19.634	24.54	1430	1395		- 2	8¼" Casing, 24.38 lbs.
75	8.640	0.281	0.274	19.649	24.44	1375	1345		- 5.5	8" Line Pipe, 25.00 lbs.
*77	8.660	0.281	0.274	19.581	24.47	1275	1245		-12.5	" " " " "
*78	8.660	0.281	0.280	18.396	25.68	1250	1145		-20	" " " " "
	8.660		0.268	19.642	24.03	1419	1446		+ 1.2	20' Lengths, Corrected to Thk. 271. *Iron, not in averages.
118	8.645		0.294	2.158	26.22	2450	2780		+10.5	
122	8.645		0.298	2.160	26.60	2365	2655		+ 5.5	2½' Foot Lengths.
121	8.657	0.322	0.319	2.170	28.43	2290	2325	2515	- 7.5	
119	8.641		0.322	2.146	28.66	2490	2490		- 1	8" Line Pipe, 28.18 lbs.
120	8.648		0.323	2.150	28.64	2390	2380		- 5.5	
	8.646		0.311	2.157	27.70	2397	2526		+ 0.4	
115	8.658		0.297	4.645	26.48	1980	2270		- 1	
117	8.634		0.299	4.641	26.58	2325	2595		+13	5 Foot Lengths.
113	8.643	0.322	0.307	4.646	27.36	1795	1970	2290	-14	
114	8.673		0.307	4.635	27.43	2040	2220		- 3	8" Line Pipe, 28.18 lbs.
116	8.663		0.321	4.656	28.60	2225	2240		- 2	
	8.654		0.306	4.642	27.28	2073	2259		- 1.4	
110	8.626		0.306	9.640	27.20	2055	2235		- 4.5	
†112	8.672	0.322	0.314	9.645	28.04	1585	1675	2135	-21.5	10 Foot Lengths.
†108	8.652		0.325	9.640	28.96	1780	1750		+ 4	8" Line Pipe, 28.18 lbs.
	8.626		0.306	9.640	27.20	2055	2235		- 4.5	†O.H. Steel, not in averages.
123	8.645	0.281	0.297	14.641	26.49	1675	1940		- 4.5	8" Line Pipe, 25.00 lbs.
165	8.648	0.322	0.297	14.645	26.46	1520	1785		-12.5	" " " 28.18 lbs.
166	8.672	0.322	0.308	14.635	27.48	1685	1835	2035	- 9.5	" " " " "
103	8.641	0.322	0.320	14.640	28.38	2000	2025		- 0.5	" " " " "
107	8.666	0.322	0.324	14.630	28.89	2025	2005		- 1.5	" " " " "
	8.658		0.309	14.638	27.54	1781	1918		- 5.6	15 Foot Lengths.
101	8.647		0.299	19.641	26.27	1650	1935		- 1.5	
100	8.646		0.297	19.645	26.44	1710	1970		+ 0.5	
424	8.671		0.302	19.885	26.98	1575	1780		- 9.5	
423	8.649		0.303	19.792	27.00	1830	2025		+ 3	20 Foot Lengths
421	8.666	0.322	0.303	19.760	27.09	1935	2135	1965	+ 8.5	
102	8.656		0.303	19.658	27.00	1960	2160		+10	8" Line Pipe, 28.18 lbs.
422	8.672		0.307	19.765	27.39	1635	1790		- 9	
†98	8.666		0.308	19.636	27.44	1735	1890		- 4	
420	8.658		0.310	19.875	27.64	1805	1936		- 1.5	
	8.658		0.302	19.753	26.98	1762	1946		+ 0.1	
1	2	3	4	5	6	7	8	9	10	11

FIG. 10. ARRANGEMENT OF TESTS IN SERIES ONE

averages contained in column 8, Figs. 8, 9, 10. By means of these plotted values the curves marked *M* were constructed. The spacing of these curves was adjusted so that when the values of the table on Figs. 8, 9, 10 were also plotted to collapsing pressure and thickness, for each of the five lengths tested, the resulting curves were smooth. By this method of cross-plotting the individual experiments on 8⅝ inches outside diameter tubes, the four curves marked *M* were obtained. Each of these curves, then, is not based only upon the group averages belonging to it, but is also based upon the group averages belonging to the other three curves similarly marked.

The curves marked *N* were obtained by adjusting the curves *M* so as to harmonize with the most probable values for collapsing pressure as based upon Series Two. The difference, it will be observed, is small, the different curves *N* being only 5.6 per cent. below the corresponding curves *M*.

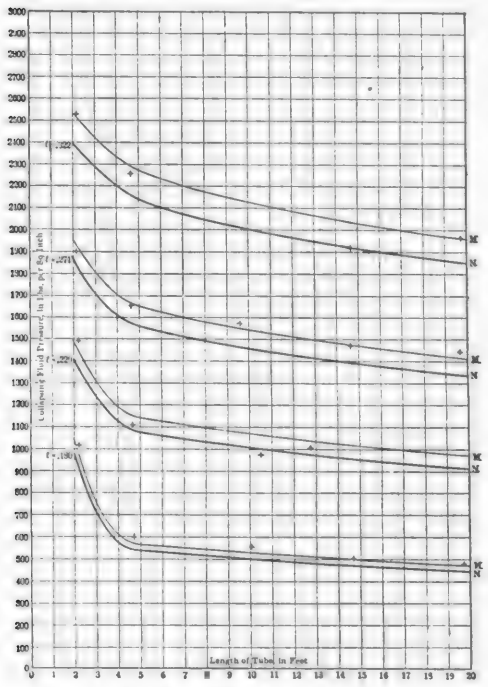


FIG. 11. CHART SHOWING RELATION OF LENGTH OF TUBE TO COLLAPSING PRESSURE, BASED UPON TESTS ON LENGTHS OF 2½, 5, 10, 15 AND 20 FEET.

Note that the group averages with collapsing pressures reduced to nominal thickness are represented by combined circles and crosses (-o-). The light lines, marked M, show the relation of length to collapsing pressure, deduced from tests on tubes 8⅝-ins. O. D., and the heavy lines marked N, 5.6% below the corresponding light lines show the relation as based on all tests on outside diameters from 3 to 10 inches.

It must be remembered that this chart applies strictly only to tubes having an outside diameter of 8⅝ inches.

DISCUSSION OF CURVES *M* AND *N*

An inspection of Fig. 11 discloses the fact that for this size of tube, especially for the thinner walls, there is a marked dropping off in collapsing pressure as the length of tube is increased up to about 4½ feet, or until a length equal to about 6 diameters is reached. Beyond this point there appears to be no further material decrease in the collapsing pressure. For example, from curve *M*, for a thickness of 0.180 inch, the collapsing pressures for lengths of 2, 4½ and 20 feet are respectively 1,050, 570, 480 pounds. That is to say, an increase in length from 2 to 4½ feet diminishes the collapsing pressure by 480 pounds, while a further increase from 4½ to 20 feet in length diminishes the collapsing pressure by only 90 pounds. As the thickness of wall is increased this disparity between the relative strength of long and short tubes becomes less prominent until for a thickness of 0.322 inch the difference is so small as to be of no practical importance.

Assuming 20 feet to be the standard length of tube between end connections tending to hold it to a circular form, we find from curve *N*, for a thickness of 0.180 inch, that for lengths of 20, 15, 10, 5 and 2 feet, the respective collapsing pressures would be 450, 470, 500, 540 and 980, which correspond to increases of 4.5, 11, 20 and 118 per cent., respectively.

For a thickness of 0.322 inch the values of the collapsing pressures for the same lengths are 1,850, 1,915, 2,000, 2,140 and 2,390, which correspond to increases of 3, 5, 8, 16 and 29 per cent. respectively.

A study of these curves *M* and *N* will show conclusively that for lengths greater than about six diameters the strength of a tube when subjected to a fluid collapsing pressure is substantially constant. It must be remembered that the inability to stop the hydraulic pressure pump instantly the experimental tube failed, together with the recoil of the hydraulic test cylinder, will account for an extension of the length of the collapsed portion by probably two or more diameters, after failure had actually occurred.

Collapsing Tests, Series Two, on Twenty-Foot Lengths

The purpose of Series One was to determine the precise nature of the influence of length of tube upon the collapsing pressure. By length of tube is here meant the distance between couplings, or other end connections, of a single length of tube, tending to hold it to a circular form. The experimental determinations constituting Series One, show conclusively that for commercial wrought tubes 8⅝ inches outside diameter, there is no practical difference in the collapsing pressure for lengths greater than six diameters up to

COLLAPSING PRESSURES.— Abstract from Log of Tests Conducted by Prof. R. T. Stewart, 1902-04, on National Tube Co's Lap-welded Bessemer Steel Tubes, 20 Foot Lengths, to which is added a Comparison with Calculated Values, by Formulae A&B. Made by E.E.S. under direction of R.T.S., 1905.

Tests Grouped according to Outside Diameter and Arranged in Order of Thicknesses of Tubes.

Number of Test	Outside Diameter, Inches.		Thickness of Wall, Inches.		Actual Plain End Weight, Lbs. per Ft.	Collapsing Pressure Pounds per Square Inch			Commercial Designation of Tube, as Reported.
	Nominal	Actual	Nominal	Computed from Wgt.		Observed	Calc'd by Formula	%Variation from Calc'd	
480		2.999	0.109	0.110	3.40	1550	1793	-13.6	3" Standard Boiler Tubing, 3.33#
482		3.006	0.109	0.110	3.40	1630	1786	- 8.7	" " " " "
483		3.001	0.109	0.110	3.40	1725	1791	- 3.7	" " " " "
484		2.993	0.109	0.111	3.43	2025	1828	+10.8	" " " " "
487	3.000	2.998	0.120	0.112	3.45	1960	1852	+ 5.8	" Locomotive " " 3.63#
485		2.996	0.120	0.112	3.45	1800	1865	- 3.5	" " " " "
486		2.997	0.120	0.112	3.45	1850	1853	- 0.2	" " " " "
487		2.998	0.120	0.113	3.48	2175	1887	+15.3	" " " " "
488		2.998	0.120	0.114	3.53	2025	1910	+ 6.0	" " " " "
Average		2.997		0.112	3.44	1860	1841	+ 0.9	
491	3.000	2.987	0.15	0.139	4.23	2575	2647	- 2.7	3" Special, 4.57 lbs.
490		2.997		0.147	4.48	3350	2865	+16.9	
Average		2.992		0.143	4.35	2962	2756	+ 7.1	
498		3.000		0.182	5.48	3700	3872	- 4.4	
499		2.994		0.189	5.65	4200	4085	+ 2.8	
495	3.000	2.990	0.18	0.190	5.68	4200	4122	+ 1.9	3" Special, 5.42 lbs.
497		2.997		0.190	5.68	4175	4109	+ 1.6	
496		2.996		0.191	5.73	4200	4140	+ 1.5	
Average		2.995		0.188	5.64	4095	4066	+ 0.7	
464		3.992		0.114	4.71	860	1089	-21.0	
460		3.990		0.119	4.91	925	1199	-22.8	
463	4.000	4.001	0.120	0.120	4.98	1030	1214	-15.2	4" Converse Joint, 4.89 lbs.
461		3.990		0.122	5.06	975	1264	-22.9	
462		3.990		0.122	5.03	1030	1264	-18.5	
Average		3.993		0.119	4.94	964	1206	-20.1	
469		4.017		0.169	6.94	2160	2261	- 4.5	
465		4.010		0.173	7.08	2050	2353	-12.9	
467	4.000	4.012	0.18	0.173	7.11	2425	2351	+ 3.1	3½" English, 7.35 lbs.
466		4.014		0.178	7.28	2225	2457	- 9.4	
468		4.018		0.184	7.53	2540	2583	- 1.7	
Average		4.014		0.175	7.19	2280	2401	- 5.1	
474		4.019		0.205	8.32	3075	3035	+ 1.3	
472		4.029		0.210	8.57	3150	3132	+ 0.6	
471	4.000	4.024	0.226	0.213	8.67	3125	3202	- 2.4	3½" Full Weight, 9.00 lbs.
470		4.029		0.215	8.77	3125	3239	- 3.5	
473		4.028		0.217	8.82	3375	3283	+ 2.8	
Average		4.026		0.212	8.63	3170	3178	- 0.2	
475		4.020		0.324	12.79	5525	5680	- 1.3	
478		4.011		0.326	12.85	5600	5659	- 1.0	
477	4.000	4.016	0.321	0.324	12.85	5625	5650	- 0.4	3½" Extra Strong, 12.47 lbs.
479		4.018		0.328	12.99	5425	5704	- 4.9	
476		4.012		0.332	13.05	5625	5786	- 2.8	
Average		4.014		0.327	12.89	5560	5696	- 2.1	
200		6.018		0.123	7.77	450	424	+ 6.1	
201		6.026		0.127	8.00	500	462	+ 8.2	
209		6.016		0.128	8.07	485	475	+ 2.1	
206		6.021		0.129	8.12	480	485	- 1.0	
203	6.000	6.017	0.134	0.130	8.19	540	496	+ 8.9	6" Converse Joint, 8.26 lbs.
202		6.015		0.130	8.19	575	498	+15.5	
204		6.010		0.131	8.24	530	511	+ 3.7	
205		6.023		0.131	8.22	530	507	+ 4.5	
207		6.013		0.134	8.45	640	547	+17.0	
208		6.013		0.135	8.45	510	560	- 8.9	
Average		6.017		0.130	8.17	524	497	+ 5.6	
1	2	3	4	5	6	7	8	9	10

FIG. 12. ARRANGEMENT OF TESTS IN SERIES TWO

COLLAPSING PRESSURES.— Abstract from Log of Tests Conducted by Prof. R. T. Stewart, 1902-04, on National Tube Co's Lap-welded Bessemer Steel Tubes, 20 Foot Lengths, to which is added a Comparison with Calculated Values, by Formulae A&B. Made by E.E.S. under direction of R.T.S., 1905.

Tests Grouped according to Outside Diameter and Arranged in Order of Thicknesses of Tubes.

Number of Test	Outside Diameter, Inches.		Thickness of Wall, Inches.		Actual Plain End	Collapsing Pressure Pounds per Square Inch.			Commercial Designation of Tube, as Reported.
	Nominal	Actual.	Nominal.	Computed from Wgt.	Weight, Lbs. per Ft.	Observed	Calc'd by Formula	% Variation from Calc'd	
216		6.028	0.156	0.155	9.75	760	843	- 9.8	$5\frac{5}{8}$" Casing, 10.46 lbs
222		6.037	0.156	0.156	9.79	880	854	+ 3.1	" " " "
213		6.037	0.156	0.164	10.30	850	968	-12.2	" " " "
224		6.026	0.156	0.166	10.40	1110	1002	+10.8	" " " "
225		6.038	0.156	0.166	10.39	715	997	-28.3	" " " "
221		6.034	0.156	0.166	10.40	760	998	-23.8	" " " "
212		6.011	0.156	0.166	10.35	950	1008	- 5.8	" " " "
219		6.021	0.156	0.166	10.37	980	1003	- 2.3	" " " "
210	6.000	6.007	0.156	0.167	10.44	1025	1024	+ 0.1	" " " "
238		6.037	0.156	0.167	10.45	775	1011	-23.3	" " " "
231		6.034	0.156	0.168	10.50	1050	1027	+ 2.2	" " " "
218		6.008	0.156	0.168	10.50	860	1037	-17.1	" " " "
215		6.033	0.156	0.168	10.55	1010	1028	- 1.7	" " " "
211		6.024	0.156	0.169	10.59	930	1046	-11.1	" " " "
223		6.026	0.156	0.169	10.54	1070	1045	+ 2.4	" " " "
243		6.034	0.220	0.170	10.62	875	1056	-17.1	" " 14.20 "
214		6.031	0.156	0.171	10.69	1090	1071	+ 1.8	" " 10.46 "
217		6.038	0.156	0.175	10.92	1010	1126	-10.3	" " " "
Average		6.028		0.167	10.42	928	1008	- 7.9	
226		6.028	0.156	0.178	11.14	1425	1173	+21.5	$5\frac{5}{8}$" Casing, 10.46 lbs.
247		6.055	0.220	0.179	11.22	1010	1176	-14.1	" " 14.20 "
240		6.035	0.220	0.179	11.19	1095	1145	- 7.6	" " " "
259		6.024	0.203	0.182	11.35	1100	1233	-10.8	" " 12.04 "
258		6.013	0.203	0.182	11.30	1350	1237	+ 9.1	" " " "
253		6.020	0.203	0.184	11.45	958	1263	-24.8	" " " "
242	6.000	6.035	0.220	0.185	11.57	1272	1271	+ 0.1	" " 14.20 "
256		6.021	0.203	0.185	11.55	1450	1277	+13.5	" " 12.04 "
257		6.025	0.203	0.189	11.77	1258	1333	- 6.2	" " " "
255		6.028	0.203	0.192	11.98	790	1375	-42.5	" " " "
250		6.016	0.203	0.192	11.96	1458	1388	+ 5.1	" " " "
245		6.010	0.220	0.193	11.97	1375	1397	- 1.6	" " 14.20 "
244		5.998	0.220	0.193	11.97	1750	1403	+24.7	" " " "
Average		6.024		0.186	11.57	1251	1285	- 2.6	
251		6.016	0.203	0.214	13.25	1750	1697	+ 3.1	$5\frac{5}{8}$" Casing, 12.04 lbs.
241		6.021	0.220	0.219	13.57	1600	1767	- 9.4	" " 14.20 "
254		6.005	0.203	0.220	13.59	1550	1789	-13.4	" " 12.04 "
252	6.000	6.020	0.203	0.222	13.73	2075	1810	+14.6	" " " "
*249		6.036	0.220	0.228	14.15	1200	1888	-36.4	" " 14.20 "
246		6.001	0.220	0.230	14.17	1900	1936	- 1.9	" " " "
248		6.004	0.220	0.232	14.30	1800	1963	- 8.3	" " " "
Average		6.011		0.222	13.77	1779	1827	- 2.5	*Defective, not in averages.
415		6.072	0.271	0.250	15.53	2220	2183	+ 1.7	$5\frac{5}{8}$" Casing, 16.70 lbs.
261		6.027	0.271	0.251	15.49	1750	2223	-21.3	" " " "
279		6.072	0.271	0.254	15.79	2360	2240	+ 5.4	" " " "
276		6.033	0.271	0.259	15.94	2475	2335	+ 6.0	" " " "
*260		6.054	0.271	0.260	16.06	1755	2336	-24.9	" " " "
264		6.022	0.271	0.260	15.99	2450	2356	+ 4.0	" " " "
416		6.042	0.271	0.262	16.16	2555	2372	+ 7.7	" " " "
†262		6.033	0.271	0.263	16.20	2600†	2392	+ 8.7	" " " "
282		6.024	0.271	0.267	16.44	2250	2456	- 8.4	" " " "
442	6.000	5.990	0.28	0.269	16.45	2590	2586	+ 3.4	6" O.D. Special, 17.12 lbs.
441		5.993	0.28	0.269	16.45	2150	2504	-14.1	" " " " "
273		6.021	0.271	0.270	16.59	2270	2501	- 9.2	$5\frac{5}{8}$" Casing, 16.70 lbs.
285		6.022	0.271	0.270	16.55	2550	2500	+ 2.0	" " " "
443		5.998	0.28	0.271	16.55	2460	2530	- 2.8	6" O.D. Special, 17.12 lbs.
417		6.042	0.271	0.271	16.71	2400	2501	- 4.0	$5\frac{5}{8}$" Casing, 16.70 lbs
419		6.044	0.271	0.271	16.73	2575	2500	+ 3.0	" " " "
440		5.991	0.28	0.273	16.68	2780	2563	+ 8.5	6" O.D. Special, 17.12 lbs.
444		5.993	0.28	0.274	16.73	2455	2576	- 4.7	" " " " "
418		6.044	0.271	0.277	17.08	2890	2586	+11.8	$5\frac{5}{8}$" Casing, 16.70 lbs
263		6.025	0.271	0.280	17.17	2600	2642	- 1.6	" " " "
Average		6.026		0.266	16.38	2441	2446	- 0.2	*Defective, not in averages. †Did not collapse.
1	2	3	4	5	6	7	8	9	10

FIG. 13. ARRANGEMENT OF TESTS IN SERIES TWO

COLLAPSING PRESSURES.— Abstract from Log of Tests Conducted by Prof R. T. Stewart, 1902-04, on National Tube Co.'s Lap-welded Bessemer Steel Tubes, 20 Foot Lengths, to which is added a Comparison with Calculated Values, by Formulae A&B. Made by E. E. S. under direction of R. T. S., 1905.

Tests Grouped according to Outside Diameter and Arranged in Order of Thicknesses of Tubes.

Number of Test.	Outside Diameter Inches. Nominal	Outside Diameter Inches. Actual	Thickness of Wall, Inches. Nominal	Thickness of Wall, Inches. Computed from Wgt.	Actual Plain End Weight, Lbs. per Ft.	Collapsing Pressure Pounds per Square Inch. Observed	Collapsing Pressure Pounds per Square Inch. Calc'd by Formula.	Collapsing Pressure Pounds per Square Inch. %Variation from Calc'd	Commercial Designation of Tube, as Reported.
402		6.625	0.15	0.152	10.57	585	571	- 1.6	6⅝" O.D. Special, 10.39 lbs.
404		6.657	0.15	0.153	10.59	520	606	-14.2	" " " " "
403	6.625	6.661	0.15	0.154	10.67	560	618	- 9.4	" " " " "
*400		6.663	0.15	0.154	10.68	400	617	-35.2	" " " " "
300		6.657	0.172	0.157	10.87	710	658	- 7.9	6¼" Casing, 11.58 lbs.
401		6.658	0.15	0.157	10.87	585	658	-11.1	6⅝" O.D. Special, 10.39 lbs.
Average		6.660		0.155	10.71	592	626	- 8.7	*Defective, not in averages. See log.
303		6.653		0.164	11.35	730	750	- 2.7	
304	6.625	6.652	0.172	0.165	11.42	600	764	-21.5	6¼" Casing, 11.58 lbs.
301		6.657		0.165	11.47	720	762	- 5.5	
302		6.653		0.168	11.62	630	803	-21.5	
Average		6.654		0.166	11.47	670	770	-12.8	
305		6.680		0.196	13.57	1100	1157	- 4.9	
309		6.676		0.196	13.57	1075	1159	- 7.2	
306	6.625	6.693	0.203	0.200	13.85	1285	1204	+ 0.1	6¼" Casing, 13.32 lbs.
307		6.682		0.202	13.99	1275	1234	+ 3.3	
308		6.687		0.205	14.17	1265	1271	- 0.5	
Average		6.684		0.200	13.83	1184	1205	-1.8	
410		6.686		0.241	16.59	1680	1738	- 3.3	
413		6.679		0.248	16.99	1710	1832	- 6.7	
414		6.682		0.248	17.01	1615	1831	-11.8	
*313		6.657		0.250	17.09	1820	1869	- 2.6	
314	6.625	6.671	0.238	0.251	17.20	2175	1875	+16.0	6¼" Casing, 17.02 lbs.
411		6.684		0.251	17.24	1940	1869	+ 3.8	
312		6.669		0.252	17.25	1975	1889	+ 4.6	
311		6.674		0.254	17.39	2160	1913	+12.9	
412		6.675		0.256	17.51	1780	1938	- 8.2	
Average		6.677		0.250	17.15	1879	1861	+ 0.9	*Iron, not in averages.
310		6.661	0.238	0.260	17.74	2275	1997	+13.9	6¼" Casing, 17.02 lbs.
408		6.651	0.280	0.261	17.81	2060	2015	+ 2.2	6" Full Weight, 18.76 lbs.
405	6.625	6.650	0.280	0.262	17.85	2135	2028	+ 5.3	" " " " "
406		6.653	0.280	0.262	17.85	1975	2027	- 2.6	" " " " "
407		6.655	0.280	0.278	18.94	2560	2234	+14.6	" " " " "
409		6.654	0.280	0.284	19.35	2390	2313	+ 1.2	" " " " "
Average		6.652		0.268	18.24	2224	2102	+ 5.8	
439		7.009	0.148	0.153	11.21	515	513	+ 0.4	7" Converse Joint, 10.65 lbs.
317		7.043	0.180	0.154	11.31	575	515	+11.6	6⅝" Casing, 12.34 lbs.
437		7.009	0.148	0.155	11.31	685	533	+13.5	7" Converse Joint, 10.65 lbs.
316		7.040	0.180	0.158	11.58	550	559	- 1.6	6⅝" Casing, 12.34 lbs.
315	7.000	7.046	0.180	0.158	11.61	570	558	+ 2.2	" " " "
435		7.068	0.148	0.161	11.75	665	605	+ 9.9	7" Converse Joint, 10.65 lbs.
438		7.015	0.148	0.162	11.85	675	615	+ 9.8	" " " " "
319		7.059	0.180	0.163	11.94	540	615	-12.2	6⅝" Casing, 12.34 lbs.
318		7.033	0.180	0.166	12.13	580	660	-12.1	" " " "
436		7.015	0.148	0.168	12.25	645	690	- 6.5	7" Converse Joint, 10.65 lbs.
Average		7.028		0.160	11.70	592	586	+ 1.5	
322		7.057		0.233	16.97	1525	1476	+ 3.3	
321		7.050		0.241	17.50	1575	1577	- 0.1	
324	7.000	7.050	0.248	0.245	17.76	1775	1626	+ 9.2	6¼" Casing, 17.51 lbs.
323		7.045		0.245	17.77	1675	1628	+ 2.9	
324		7.047		0.248	18.02	1850	1664	+11.2	
Average		7.050		0.242	17.60	1680	1594	+ 5.3	
432		7.018		0.268	19.33	1835	1924	- 4.6	
434		6.984		0.269	19.34	1975	1932	+ 1.2	
431	7.000	6.975	0.28	0.283	20.23	2300	2130	+ 8.0	7" O.D. Special, 20.12 lbs.
433		6.974		0.287	20.47	2180	2181	- 0.0	
430		6.984		0.290	20.74	2445	2213	+10.5	
Average		6.987		0.279	20.02	2147	2080	+ 3.0	
1	2	3	4	5	6	7	8	9	10

FIG. 14. ARRANGEMENT OF TESTS IN SERIES TWO

COLLAPSING PRESSURES.— Abstract from Log of Tests Conducted by Prof R. T. Stewart, 1902-04, on National Tube Co.'s Lap-welded Bessemer Steel Tubes, 20 Foot Lengths, to which is added a Comparison with Calculated Values, by Formulae A&B. Made by E.E.S. under direction of R.T.S., 1905.

Tests Grouped according to Outside Diameter and Arranged in Order of Thicknesses of Tubes.

Number of Test.	Outside Diameter, Inches.		Thickness of Wall, Inches.		Actual Plain End Weight, Lbs. per Ft.	Collapsing Pressure, Pounds per Square Inch.			Commercial Designation of Tube, as Reported.
	Nominal.	Actual.	Nominal	Computed from Wgt.		Observed	Calc'd by Formula	% Variation from Calc'd.	
1	8.625	8.657	0.180	0.176	15.92	450	418	+ 7.7	8¼" Casing, 16.07 lbs.
4		8.640		0.183	16.54	450	469	- 4.0	
3		8.641		0.186	16.77	535	491	+ 9.0	
2		8.637		0.191	17.24	625	534	+17.0	
5		8.638		0.191	17.23	620	533	+16.3	
Average		8.643		0.185	16.74	536	489	+ 9.2	
26	8.625	8.604	0.229	0.219	19.57	870	820	+ 6.1	8¼" Casing, 20.10 lbs.
52	8.625	8.664	0.271	0.258	23.13	1320	1195	+10.5	8¼" Casing, 24.38 lbs.
54		8.660	0.271	0.262	23.52	1485	1236	+20.1	" " " "
99		8.663	0.322	0.264	23.66	1375	1255	+ 9.6	8" Line Pipe, 28.18 lbs.
50		8.660	0.271	0.271	24.28	1435	1326	+ 8.2	8¼" Casing, 24.38 lbs.
53		8.660	0.271	0.272	24.32	1520	1336	+13.8	" " " "
76		8.663	0.281	0.272	24.38	1410	1335	+ 5.6	8" Line Pipe, 25.00 lbs.
75		8.640	0.281	0.274	24.44	1375	1363	+ 0.9	" " " " "
51		8.668	0.271	0.274	24.54	1430	1354	+ 5.6	8¼" Casing, 24.38 lbs.
*77		8.660	0.281	0.274	24.47	1275	1356	- 6.0	8" Line Pipe, 25.00 lbs.
*78		8.660	0.281	0.280	25.08	1250	1416	-11.7	" " " " "
Average		8.660		0.268	24.03	1419	1300	+ 9.3	*Iron, not in averages.
101	8.625	8.647	0.322	0.294	26.27	1450	1561	+ 5.7	8" Line Pipe, 28.18 lbs.
100		8.642	0.322	0.297	26.44	1710	1591	+ 7.5	" " " " "
424		8.671	0.322	0.302	26.98	1575	1633	- 3.5	8" Full Weight, 28.18 lbs.
102		8.656	0.322	0.303	27.00	1960	1648	+18.9	8" Line Pipe, 28.18 lbs.
423		8.649	0.322	0.303	27.00	1830	1650	+10.9	8" Full Weight, 28.18 lbs.
421		8.666	0.322	0.303	27.09	1935	1644	+17.7	" " " " "
422		8.672	0.322	0.307	27.39	1635	1682	- 2.8	" " " " "
†98		8.666	0.322	0.308	27.44	1735	1694	+ 2.4	8" Line Pipe 28.18 lbs.
426		8.658	0.322	0.310	27.64	1805	1717	+ 5.1	8" Full Weight, 28.18 lbs.
Average		8.658		0.302	26.98	1762	1641	+ 7.4	†O. H. Steel, not in averages.
*427	8.625	8.678	0.363	0.346	30.82	1830	2070	-11.6	8" Oil Well Tubing, 32.66 lbs.
*425		8.666		0.349	31.00	2180	2104	+ 3.6	
*428		8.664		0.353	31.36	2045	2145	- 4.7	
*429		8.643		0.356	31.62	1930	2167	-10.9	
*426		8.672		0.364	32.36	2155	2252	- 4.3	
Average		8.673		0.354	31.42	2028	2148	- 5.6	*Iron, group rejected.
449	10.000	10.055	0.156	0.157	16.55	210	219	- 4.1	10" Converse Joint, 16.18 lbs.
447		10.045		0.166	17.50	240	250	- 4.0	
445		10.037		0.167	17.58	210	254	-17.3	
446		10.031		0.167	17.59	225	254	-11.4	
448		10.035		0.170	17.94	240	265	- 9.4	
Average		10.041		0.165	17.43	225	248	- 9.2	
452	10.000	10.005	0.203	0.185	19.43	305	327	- 6.7	10" Boiler Tubing, 21.60 lbs.
453		10.033		0.190	19.94	395	347	+13.8	
451		10.029		0.194	20.35	390	367	+ 6.3	
454		10.037		0.195	20.54	400	371	+ 7.8	
450		10.027		0.206	21.57	425	430	- 1.2	
Average		10.026		0.194	20.37	383	368	+ 4.0	
456	10.000	9.990	0.30	0.312	32.27	1350	1321	+ 2.2	10" O.D. Special, 31.07 lbs.
459		10.023		0.314	32.61	1385	1329	+ 4.2	
457		9.989		0.317	32.71	1275	1364	- 6.5	
458		10.003		0.317	32.81	1305	1360	- 4.0	
455		10.000		0.319	33.01	1280	1379	- 7.2	
Average		10.001		0.316	32.68	1319	1351	- 2.3	
1	2	3	4	5	7	8	9		10

Formula A, $P = 1000\left(1-\sqrt{1-1600\frac{t}{d}}\right)$. Formula B, $P = 86670\frac{t}{d} - 1386$.

P = collapsing fluid pressure, in lbs. per sq. in., t = thickness of wall in inches, d = outside dia. of tube in inches.

Formula B applies only to values of $\frac{t}{d}$ greater than 0.227, or pressures greater than 581 pounds, while formula A applies only to values less than these.

FIG. 15. ARRANGEMENT OF TESTS IN SERIES TWO

twenty feet. As soon as this point had been fully established experimentally it was decided to make all succeeding tests on tubes in lengths of 20 feet. This was accordingly done, the results of these tests being grouped as Series Two.

The apparatus used, and the manner of making the tests of Series Two were, in every essential respect, precisely the same as for Series One.

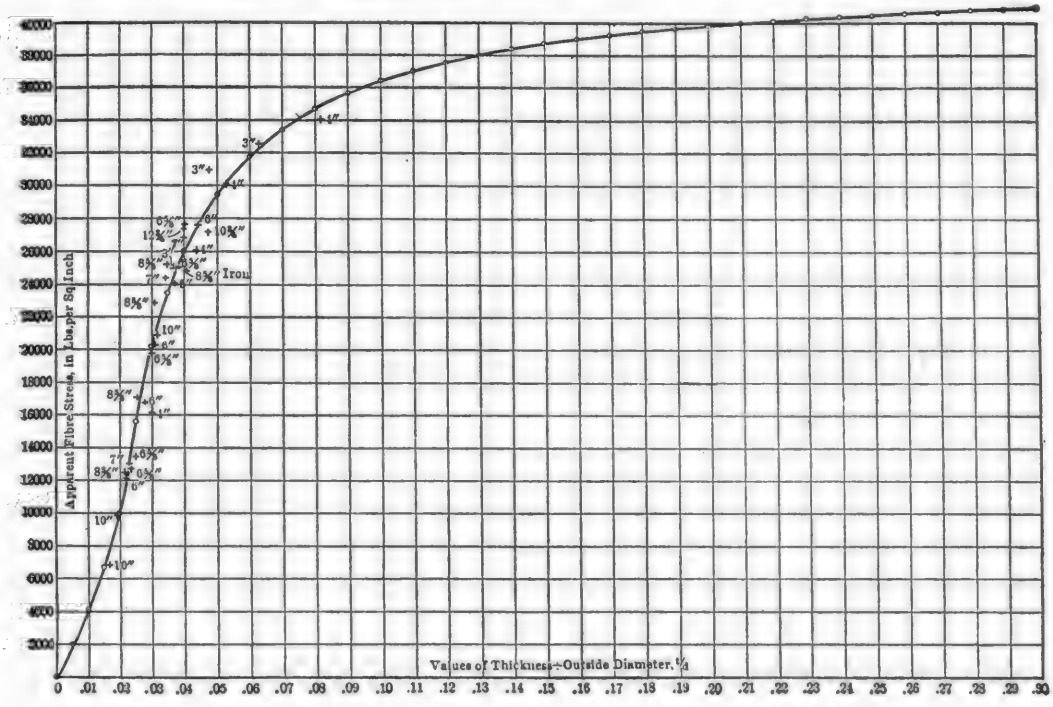


FIG. 16. CHART SHOWING ACTUAL AND CALCULATED COLLAPSING PRESSURES PLOTTED TO THICKNESS ÷ DIAMETER t/d, BASED ON TESTS ON 20 FOOT LENGTHS

Formula A, for $^t/_d$ less than 0.0227,

$$P=1{,}030\ \left(1=\sqrt{1-1{,}600\ {}^{t^2}/_{d^2}}\right)$$

Formula B, for $^t/_d$ greater than 0.0227,

$$p=86{,}670\ {}^t/_d-1{,}386,$$

where P = collapsing fluid pressure in lbs. per sq. inch, d = outside diameter of tube in inches, t = thickness of wall in inches.

Note that crosses (+) represent group averages of tests, the attached figures being outside diameters, while circles (○) represent calculated values.

Derivation of Formulae for the Probable Collapsing Pressure of Lap-Welded Bessemer Steel Tubes for Lengths of Twenty Feet

GROUPING OF TESTS

The first step taken toward the derivation of formulæ for the strength of wrought tubes subjected to external fluid pressure, as based upon the results of the present research, was the grouping of the tests as shown in Figs. 12, 13, 14 and 15.

This table contains an abstract from the Log of the results of all tests on tubes in lengths of 20 feet, excepting those that were intentionally dinged or put out of round, before being tested, for the purpose of obtaining data on the results of such defects.

It will be observed that the tests in this table are grouped according to the outside diameter of tube, and, for each diameter, are arranged in the order of thickness of wall.

PLOTTING GROUP AVERAGES TO $\frac{t}{d}$

It is apparent that for tubes subjected to external fluid pressure there are three principal variables involved, namely, the outside diameter, *d*, the thickness of wall, *t*, and the fluid-collapsing pressure, *P*. It is also apparent that each of these variables is a function of the other two; that is to say, depends jointly upon each of them for its value.

After a fruitless effort to derive a satisfactory formula on the basis of three variables, which, when plotted, would, of course, be a surface in space, the thought

happily presented itself that two of these variables, t and d, could be replaced by their quotient, or $\frac{t}{d}$, which, of course, might be treated as a single variable. By the adoption of this expedient, matters were greatly simplified, since it thus became possible to plot the results of the tests for all diameters and thicknesses of wall on a plane surface.

Fig. 16 shows the group averages of Figs. 12, 13, 14 and 15 plotted in this manner; that is to say, to a vertical scale representing fluid-collapsing pressures in pounds per square inch, and a horizontal scale representing the quotient arising from dividing the thickness of wall by the outside diameter, both being expressed in inches.

FORMULA B

By an inspection of Fig. 16 it became apparent that the bulk of the group averages could be represented by a straight-line formula; indeed, all of them could be thus represented with the exception of the few having values of thickness divided by outside diameter less than 0.023. In other words, about 93 per cent. of the group averages of Figs. 12-15 can be thus represented.

On this basis, then, for values of $\frac{t}{d}$ greater than 0.023, formula B was deduced, it being as follows:

$$P = 86{,}670\ \frac{t}{d} - 1386 \quad \ldots\ldots\ldots\ldots \text{(B)}$$

Where P = collapsing pressure, pounds per square inch,
d = outside diameter of tube in inches.
t = thickness of wall in inches.

Remembering that this same formula might also have been arrived at by the substitution of proper empirical constants in a similar formula for a theoretically perfect tube, and, further, since Fig. 16 shows no apparent deviation from straightness on the upward course, it was not thought necessary to set an upper limit to the value of $\frac{t}{d}$ in the application of this formula, believing that it will give substantially correct results for all commercial lap-welded Bessemer steel tubes whose thickness divided by the outside diameter is greater than 0.023.

FORMULA A

This formula for values of $\frac{t}{d}$ less than 0.023 was derived upon the assumption that when plotted upon Fig 14 the resulting curve should be tangent to the straight line representing formula B, and be also tangent to the horizontal axis at the origin O. This arbitrary assumption gave a formula which represented very satisfactorily the few experiments in which $\frac{t}{d}$ was less than 0.023. The formula thus obtained is:

$$P = 1000\left(1 - \sqrt{1 - 1600\frac{t^2}{d^2}}\right) \quad . \quad . \text{(A)}$$

Where P, d and t are the same as for formula B.

This formula should be used for values of $\frac{t}{d}$ less than 0.023 and for P greater than $\frac{1}{22}\sqrt{d}$.

Since constructing the charts and tables contained in this paper, it was discovered that a formula having a rational form with empirical constants could be substituted for the purely empirical formula A. This formula, in addition to involving theoretical considerations of elasticity, is much the simpler of the two. It is applicable only to tubes having relatively thin walls; that is to say, to those having values of $\frac{t}{d}$ less than 0.023, and is:

$$P = 50{,}210{,}000\left(\frac{t}{d}\right)^3 \quad . \quad . \quad . \quad . \text{(G)}$$

Where P, d and t are the same as for formula A.

Either formula A or G represents satisfactorily the results of the experiments made on thin-walled tubes; that is, those in which $\frac{t}{d}$ is less than 0.023, but probably formula G will permit of the greater exterpolation.

For the Sufferers in San Francisco

With characteristic generosity, the heating trade throughout the country has responded liberally to the call for help from the sufferers in the San Francisco earthquake. The list of contributors is gratifyingly long and includes many of the best-known houses in the trade. Among the contributors are:

J. L. Mott Iron Works	$250
L. O. Koven & Brother	100
Abendroth Brothers	100
Nason Mfg. Company	100
F. N. DuBois & Co	100
Graff Furnace Company	100
T. R. McMann's Son	100
Kellogg-McCrum-Howell Company	100

Ventilation Laws in Bound Form

A limited edition of the ventilation laws of Massachusetts, New Jersey, New York and Pennsylvania, bound in vest-pocket size, has been published by the Heating and Ventilating Magazine Company. Copies of this booklet may be obtained from the publishers, 1123 Broadway, New York, at 10 cents each or 12 cents, postpaid.

THE HEATING AND VENTILATING MAGAZINE

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Manuscripts submitted for publication must in every case be accompanied by postage; otherwise they will not be returned.

AMONG the various methods described for ventilating New York's Subway, not one has contained a hint of the plan that has been actually proposed by Chief Engineer Rice in a report he has submitted to the Rapid Transit Commission. The chief engineer states that he has been engaged all winter in an effort to work out a solution of the Subway cooling problem and that the present report is a result of his work. In reading over his report, one is irresistibly reminded of the mountain that labored and brought forth a mouse. His plan, in brief, is to provide louvres or automatic air valves opening outward in the roof of the Subway, midway between stations. The movement of the proposed louvres will be dependent upon the movements of the trains, the principle being that the moving trains increase the air pressure in front of them, and as the louvres are reached, this pressure causes the valves to open. As soon as a train has passed a valve, the latter will naturally close of itself. A constant inflow of fresh air, therefore, may be expected at the station entrances. The plan provides for fourteen louvre chambers along the route of the railroad.

ACCORDING to analyses of the air in New York's Subway, it appears that in purity there is little or no difference between the Subway and street air, so that heat is the only element left to deal with. "The most desirable manner of renewing the air under these conditions," says Mr. Rice, "is to exhaust the air at the points stated. By this means the freshest air is always secured at the station, and such iron dust as may be liberated is also drawn into the interior and out through the exhaust openings there provided."

A test has already been made between two of the Subway stations with a set of these louvres and it was found that approximately 20,000 cubic feet of air per minute were discharged through 100 square feet of louvres during the hours of maximum train movement. From 1 A. M. to 5 A. M., when very few trains were running, only about 5,000 cubic feet per minute were discharged through the same area. From this experiment the conclusion is reached that if the air is to be renewed only for the purpose of ventilation, the installment of a sufficient number of louvres will unquestionably bring about the desired result, as the volume of air renewed is stated to be almost directly proportional to the number of passengers carried.

THAT such a system, however, would not be efficient in warm weather is admitted in another part of the report where reference is made to three ways that have been suggested of cooling the Subway by artificial means. These are (1) evaporation of water, (2) refrigeration and (3) the absorption of heat by disposing relatively cool water throughout the Subway. Before any method can be definitely chosen, experiments will have to be made in the summer. Mr. Rice then goes on to say that, to improve materially the conditions, there must be not only the renewal of the air but some method of cooling it. In this connection he advises the use of fans especially during the night hours when the outside temperature is at its lowest and the benefit from air renewal for cooling purposes is greatest.

The plan on the whole is another tribute to the merits of exhaust ventilation, and in its automatic features is as remarkable for its ingenuity as for its economy. It is estimated that New York's Subway can be "ventilated" in this manner for about $275,000.

EXHAUST ventilation has another advocate in Mr. Alexander Mackenzie, of Edinburgh, Scotland, whose paper on the subject, read before the Edinburgh Sanitary Society a short time ago, is reproduced in this issue. A feature of special interest in Mr. Mackenzie's paper is the comparison he made of the working costs of the upward and downward systems in two typical Edinburgh schools, both steam heated. He found that in the school with the extraction system, the air in the classrooms was changed on an average five times per hour, giving an air supply of 803 cubic feet per pupil per hour at a working cost for fuel and power to drive the fan of less than one cent per pupil per week in ordinary winter weather. The air in this school during that time averaged 7.3 parts of carbon dioxide in 10,000. In the school with the plenum system, the air was changed almost 9½ times every hour, giving an air supply of 1,646 cubic feet per pupil per hour at a working cost of 2½ cents per pupil per week in the same kind of weather. The analysis of the air in the classrooms of this school, taken the same day, gave an average of 6.7 volumes of carbon dioxide in 10,000. From these experiments, Mr. Mackenzie concludes that the greater purity of the atmosphere gained by the plenum system was attained only by supplying about double the quantity of air at four and one-half times the cost.

ON another page will be found an abstract of Professor Stewart's paper on the collapsing pressures of Bessemer steel lap-welded tubes, which he presented at the recent Chattanooga meeting of the Mechanical Engineers' Society. Owing to the unusual length of this paper, occupying as it does nearly 100 pages in the Society's volume, it is not possible to give more than a comparatively brief review of this very valuable and exhaustive research. The review as published. however, has been carefully edited by Professor Stewart, enabling him to make many desired corrections and revisions which add much to the value of the paper.

AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS

At a meeting of the Board of Governors, April 20 last, the Board named Chicago as the place for holding the semi-annual (mid-summer) meeting of the Society. The dates selected were Thursday and Friday, July 19 and 20. Former President Kent's suggestion, in his address at the last annual meeting in favor of a question-box for the Society, was taken up and discussed in the effort to secure more topics for discussion. The secretary was instructed to prepare blanks for this purpose to be sent to all the members. In order to properly edit and print the papers for the approaching meeting, members who are expecting to prepare papers are asked to have them in the secretary's hands during the early part of June.

In response to President Gormly's circular letter to the members calling upon them to do their share in the advancement of the society by preparing papers and other data, the number of contributors to the coming meeting, it is expected, will be greater than at any previous mid-summer meeting.

American Society of Mechanical Engineers

The fifty-third meeting of the Society was held at Chattanooga, Tenn., May 1 to 4 last. The social features of the meeting included the trip to the Chickamauga-Chattanooga National Military Park, where the Twelfth United States Cavalry gave a regimental drill in honor of the visitors. Also an excursion on May 3 to Lookout Mountain. On May 4, the members and ladies visited the Missionary Ridge and, in the afternoon, were taken by boat to Hales Bar, where a dam is being constructed to aid navigation and which will furnish 50,000 H. P. to the factories in Chattanooga. Among the professional papers read were: "Report of Committee on Standard Proportions for Machine Screws"; "Low Resistance Thermo-Electric Pyrometer and Compensator," by Prof. William H. Bristol; "Collapsing Pressures of Bessemer Steel Lap-welded Tubes," by Prof. R. T. Stewart, and "New Liquid Measuring Apparatus," by George B. Willcox.

New England Foundrymen's Association

New England Foundrymen's Association, at its regular meeting, held May 9 in the rooms of the Exchange Club, Boston, Mass., was addressed by Mr. E. N. Taylor, of the Department of Expert Systematizing, maintained by the Library Bureau, on the subject of "A Correct Application of True Burden to Iron Costs."

The next convention of the American Foundrymen's Association will be held in Cleveland, Ohio, on June 5, 6 and 7, 1906.

NEW DEVICES

Bundy One-Column Columbia Radiators

In the April number, in which was published views of the new Bundy Series of Columbia Radiators, manufactured by the A. A. Griffing Iron Company, Jersey

BUNDY COLUMBIA ONE-COLUMN PLAIN RADIATOR

City, N. J., a cut of a two-column plain radiator appeared over a caption of a Bundy Columbia one-column radiator. The accompanying cut is an illustration of the Columbia one-column radiator.

Spence Water Boiler

A water boiler that possesses many distinct features not found in the ordinary type of circular boiler is the "Spence" heater, made by Pierce, Butler & Pierce Manufacturing Co., of Syracuse, N. Y., who have perfected it in many ways since they took hold of the boiler several years ago. As will be seen from the illustration, the ashpit is extraordinarily deep and assures a large air and ash space to aid combustion and minimize the danger of burning out the grates.

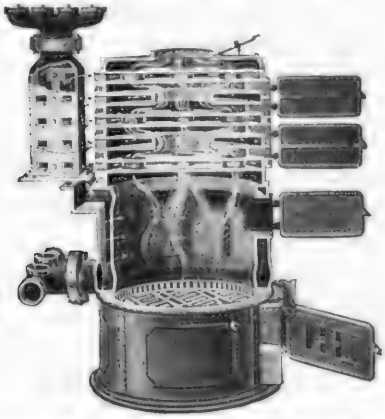
The grate proper is of the latest approved type of the combined rocking and dumping style. It is quick and positive in action, and easily operated. Should

SPENCE WATER BOILER, STYLE C

accident happen, it can be easily and quickly taken out or renewed by removal of the grate ring. The firepot is corrugated to secure a large heating surface. The water ways in the firepot are very free.

Two different types of water sections are used. The first is provided with a smoke flue in the center. In the second, the smoke flues are arranged near the outer circumference. By alternating these two styles, the flames and gases of combustion are retarded and consumed before they reach the smoke pipe.

Each section is directly connected to a water post on the back of the boiler from which circulation is made to the pipe and radiators. This feature is of value, as it insures quick circulation of the water heated in the different parts of the boiler,



INTERIOR VIEW OF SPENCE WATER BOILER, STYLE B, SHOWING WATER POST AND FIRE AND WATER TRAVEL

takes the place of a water back on the kitchen range for domestic purposes, and permits the removal of any section without disabling the system.

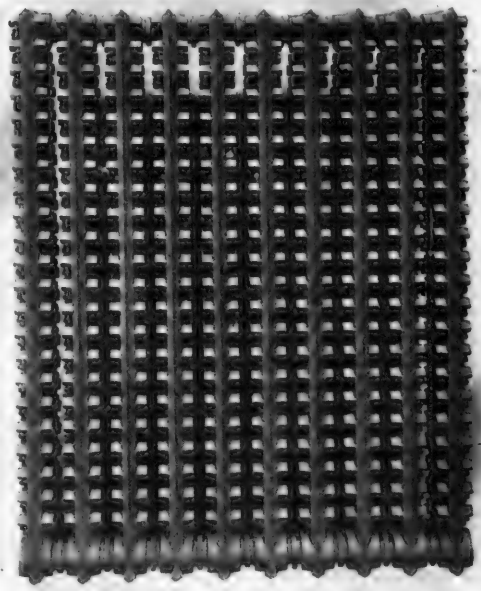
The "Spence" is made in two different styles, each possessing features designed for economy in using different kinds of fuel.

Style "B" is used for hard coal, gas and coke. Style "C" also burns hard coal, but is especially satisfactory where the cheaper grades of soft coal and coke are used.

We learn that over 50 000 of these heaters are now in use, and the company have much interesting information regarding their operation which they would be glad to give to those interested, either at their general offices at Syracuse, or at any of the branch houses in Boston, New York and Philadelphia.

The Vento Blast Heater

The Vento cast-iron blast heater, illustrated herewith, is a type of heater intro-



VENTO BLAST HEATER

duced by the American Radiator Company to the notice of a few of its customers during 1905, but it was not till the forepart of this year that the company got one of its plants in shape to extensively produce this heating surface. The sections are made in 40 and 60-inch sizes and are tapped 2½ inches. They are connected by means of cast-iron, hexagon nipples, right and left not threaded. In addition to its use for blower and heating work, the heater is also adapted for use in lumber dry-kilns, similar places, and can also be used to produce a high degree of heat in the drying rooms of laundries, washing establishments, hotels,

They may also be used in banks of heating surfaces, in chimney breeches for heating feed water. Some of the points of advantage to be noted in this heater are:

The more practical method of connecting each loop; the comparative ease of adding loops in the event of larger requirements, or of removing loops in any event, or for any reason; the relatively easy matter of handling and erecting each bank of heating surface; the much less number of screwed connections; the much larger diameter of each screwed connection, an additional safeguard against over-straining as with the many small pipes in a pipe coil; the complete elimination of wrought iron and of its constant chemical decomposition when in contact with water; the lighter weight when compared with a wrought iron coil hot blast heater of similar heating capacity.

Those interested in this form of heating surface are invited to write to the American Radiator Company for descriptive and illustrative catalogue.

Vesterdahl Refrigerating Machine

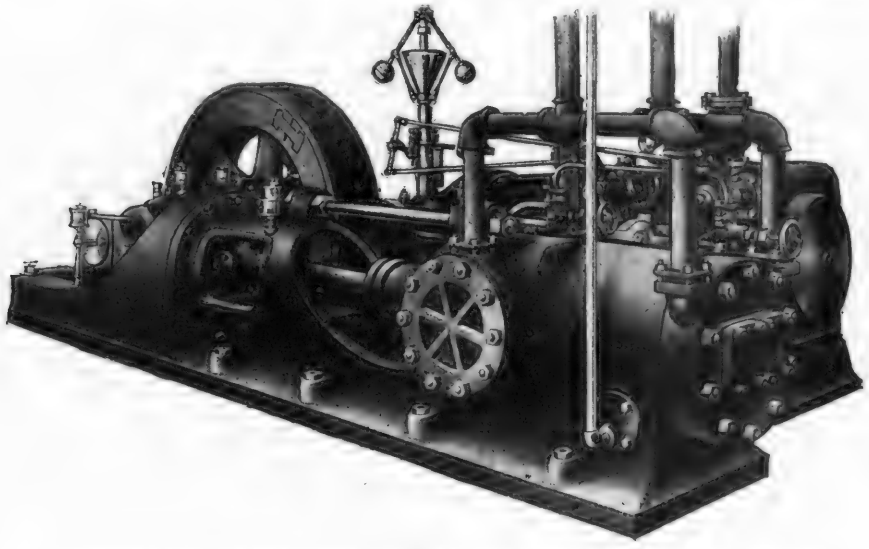
The accompanying cut illustrates an interesting type of a Vesterdahl refrigerating machine operated by the Corliss steam engine. This machine was built by the Empire State Engineering Company, of New York, whose plant, at the foot of East 116th street, is admirably equipped for this kind of work.

Heating Men in a New Coke Company

Lloyd G. McCrum, president of the McCrum-Howell Company, associated with a number of business men of Pittsburg, has formed the Thompson Connellsville Coke Company. The company has issued bonds to the amount of $3,000,000, and $2,000,000 of these bonds have been placed, the bonds being guaranteed by the Colonial Trust Company, of Pittsburg. The company has purchased a tract of 1,600 acres of coal land in Red Stone and Luzerne townships, Fayette county, at $1,400 an acre, the total consideration being $2,224 000. Sites have been chosen for the location of two modern 400-oven coke plants. In addition to Mr. McCrum, the members of the new company include: Charles Donnelly, president; A. A. Thompson, treasurer, and W. G. Rock, all of Pittsburg.

New Corporations

National Gauge Company, New York, is the name of a new firm engaged in the manufacture of gauges, thermometers, etc. The company is incorporated at $20,000 and the officers are: Henry F. Menten, president; Max Schmidt, vice-president; Emil Hoenow, treasurer, and Otto Herborn, secretary.



"VESTERDAHL" REFRIGERATING MACHINE OPERATED BY A CORLISS STEAM ENGINE

J. O'Meara, Incorporated, 141 Centre street, New York, is a new firm composed of J. O'Meara, president, and A. W. Johnston, secretary and treasurer. Mr. O'Meara is well known in the heating trade as the inventor of the O'Meara valve and of many other heating specialties that are now widely used. The firm will manufacture valves, as well as disks, wheels and parts of valves, extension spindles for radiator valves, special unions, flanges, gaskets, bolts, and also O'Meara's fire detector.

TRADE AND MISCELLANEOUS NOTES

New Books

Building Construction and Superintendence, Part III, by the late F. E. Kidder, has been received. The volume deals with trussed roofs and roof trusses and contains over 300 illustrations. Pp. 298. Size 7x9½. Published by William T. Comstock, 23 Warren street, New York, at $3.00.

Trade Literature.

Vacuum-Vapor Company have issued an eight-page folder on the subject of vacuum vapor heating that will interest many engineers. Half-tones are presented of the five devices constituting the system and the reading matter that follows fully explains the principles involved and the use to which the apparatus is put. As explained in the folder, the main difficulty with most steam heating systems is the disposing of the air in the radiators. This system obviates this by means of an ejector, discharging into a separator where the vapor condenses. The water, thus formed, returns to the boiler by gravity. The air escapes to the atmosphere through a special air trap, thence to a float valve which is surrounded by a bell-shape attachment, the lower end of which dips slightly below the surface of the water, preventing the return of the air to the radiators and boiler. As the fire in the boiler gets lower, a vacuum is immediately formed. The booklet also contains the experiences of many who have used the system.

W. K. Palmer Company, engineers, Kansas City, Mo., send us the first number of a four-page paper, entitled Office Bulletin. In the editorial announcement, it is announced that the paper will be published monthly by the company and will be devoted to extending the company's acquaintance. The enterprise corresponds, somewhat, to the publications now being issued by some of the large manufacturing houses and marks a phase of trade advertising which will be watched with especial interest by engineers who have now so few channels for successfully advertising their business.

Miscellaneous Notes

Lee Phillips, formerly with Hollis French and Allen Hubbard, consulting engineers, of Boston, Mass., has become superintendent of the contracting department of the Shaw, Kendall Engineering Company, of Toledo, Ohio.

C. W. Woodward, until recently secretary of the National Committee of the Confederate Supply Association and the Association of Manufacturers and Jobbers of Plumbing Supplies, has been presented with a handsome watch as an appreciation of his efforts in the office which he has been occupying. The committee having the matter in charge in-

HEAT YOUR HOUSE
SAVE 25 PER CENT

With our VACUUM-VAPOR method of steam heating we guarantee a saving of 25 per cent in fuel. This method will raise vapor from cold water in 20 minutes. Has no air valves on radiators, hence no leaking or hissing—no pounding—absolutely noiseless—every radiator hot from end to end. Unsatisfactory steam or hot water systems can be changed to our method at small cost and without tearing up your house. Send for booklet. VACUUM-VAPOR CO., Moline, Ill.

The Albany Return Steam Traps

have been the STANDARD for over THIRTY-TWO YEARS. For returning water under pressure to the boiler, they will perform this duty fully as well, and in many cases better than the so-called steam loop.

Send for circulars A, B, C and D.

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ALBANY STEAM TRAP CO., ALBANY, N.Y.

FREDERICK TOWNSEND, PRESIDENT

JAMES H. BLESSING, GEN. MGR.

cluded John S. Simmons, L. O. Koven and Frank S. Hanley, the presentation being made by Mr. Simmons at a luncheon.

A. A. Griffing Company, Jersey City, N. J., in company with a number of French capitalists, has opened a new boiler and radiator plant at Graville, a suburb of Havre, France, to supply the growing demand for American goods in European markets. The company is capitalized at over half a million and is equipped throughout with American machinery.

National Association of Master Plumbers of the United States has contributed $1,000 for the immediate relief of those of its members in San Francisco who are in need, the funds being placed in the hands of Mr. James E. Brick, president of the San Francisco Master Plumbers' Association. Further contributions were asked for to be directed to Charles T. Byrne, secretary, Drover's Bank Building, Forty-second and Halsted streets, Chicago.

Sirocco Fan Company, New York, advises us of an important decision in an action brought by Mr. S. C. Davidson, of the Sirocco Works, Belfast, Ireland, against The Sun Fan Company and Mr. William Tattersall, of Bradford, for infringement of one of his patents for fans now so well known over the world under the trade-mark name of "Sirocco." After hearing evidence and the argument of Mr. Walter, K.C., for the defendants, Mr. Justice Farwell, without calling on Mr. Bousfield, K.C., for the plaintiff, decided that the fans made by the Sun Fan Company and Mr. Tattersall were an infringement of Mr. Davidson's patent and gave judgment accordingly with costs, damages to be ascertained by the taking of an account.

Business Changes

The Dickinson Heating & Plumbing Co., Dickinson, N. Y., has opened business in this place.

Fargo Plumbing & Heating Co., Fargo, N. D., has increased its capital from $20,000 to $40,000.

Colwell Lead Co., New York, has increased its capital from $300,000 to $900,000 to enable the company to extend its jobbing and manufacturing departments and consolidate with it its company, American Sanitary Company, at Elizabethport, N. J. The officers of the company are: Dr. J. T. Duryea, president; S. R. Bush, vice-president; B. O. Tilden, secretary-treasurer.

Mr. C. V. Kellogg, formerly president of the Kellogg-McCrum-Howell Company, has retired from that firm, having sold his interests to Messrs. Lloyd G. McCrum and George D. Howell, his former associates. Mr. Lloyd G. McCrum

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Malleable Iron Pipe Hangers and Adjustable Beam Clamps

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68 BEEKMAN STREET, N. Y.

Logic

"If that stove saves half the coal," argued Patrick, "faith, then I'll take two, and save it all" He was like a man who finding he can save by using exhaust steam to heat his feed-water, attempts to use it *all.*

WEBSTER FEED-WATER HEATERS AND PURIFIERS

use only just enough of the exhaust to bring the feed-water up to the boiling-point. "Thoroughfare" heaters pass all of the exhaust through the heater, and also waste by back pressure. WEBSTER HEATERS save at both ends.

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has succeeded Mr. Kellogg in the office of president. Mr. Kellogg will devote himself to his interests of a similar character in the West and also to the recuperation of his health. The name of the incorporation has been changed to the McCrum-Howell Company. Mr. Kellogg's retirement was made the occasion by the entire office staff for presenting him with a silver loving cup in recognition of his uniform courtesy and consideration to the members of his staff. The presentation was made in the company's offices by Mr. John Saunderson.

Fee & Mason, manufacturers of pipe hangers and plumbers specialties, have moved from 68 Beekman street, New York, into new quarters at 81 Beekman street, where, with double the space they will be in a better position to take care of their rapidly growing business.

Standard Temperature Regulating Company, New York, has moved from 136 Liberty street to the Havemeyer Building, 26 Cortlandt street. The company reports a large number of successful installations of its heat regulation system which have given marked satisfaction.

American Radiator Company, in addition to its new address for its San Francisco office, announces additional changes as follows:

New York branch removed to 104 West 42d street, Arco Building; Pittsburg branch, 601-603 Hartje Building; Omaha branch, 417 West South 15th street; Cincinnati branch, 213 West 4th street.

Shirley Radiator & Foundry Company has sent us an announcement to the effect that, on application of its president, the Union Trust Company, of Indianapolis, has been appointed receiver for the company. It is added that this proceeding was necessary in order to secure the necessary working capital and is no reflection on the solvency of the radiator company.

San Francisco business firms engaged in the heating, ventilating and plumbing trades, have, in many cases, reinstated themselves in the stricken city. The following information concerning some of the larger firms, has been received:

National Tube Company has obtained quarters at Sixteenth and Folsom streets, San Francisco; American Radiator Company, which formerly maintained an office at 338 Crossley Building, San Francisco, has opened up new temporary quarters at 538 Hayes street, which will be the firm's address until further notice. This office is a sub-branch of the Seattle Branch, which is located at 1215-1216 Alaska Building, Seattle, Washington.

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insures the delivery of dry steam and is the most approved method for insulating and protecting pipes, conveying steam, water, gas and liquids under ground. Much more efficient and economical than wooden or masonry conduit. Absolutely watertight and not subject to deterioration. Its life and efficiency are practically unlimited.

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145

Since so much depends upon a regulating valve, why not install only the best pressure regulator obtainable?

Foster "Class W"
High Pressure Regulator

Foster "Class W"

will uniformly deliver at any desired lower pressure from a high initial pressure, regardless of the variation in the supply.

Foster Engineering Co.,
NEWARK, N. J.

New Firms.

Brew, Gallagher & Reynolds, Nashville, Tenn., have established a plumbing, steam fitting, hot water and electric work business.

Laskey & McMurrer, Boston, Mass., is the name of a new firm at 116 Broad street, which will engage in the steam fitting and ventilating business. Both men are well known, Mr. Laskey having been one of the firm of Laskey, Whitten & Jackson, and Mr. McMurrer having been foreman for Ingalls & Kendricken.

Greason & Larsen, New York, have started a steam and hot water heating business. Both Mr. Greason and Mr. Larsen were with the Greason Manufacturing Company.

Manufacturers' Notes

Kellogg-Mackay-Cameron Co., Chicago, Ill., have moved into their new quarters, the K-M-C Building, which is situated on the corner of Michigan avenue and Twelfth street. The first floor, 50x160 feet, has been fitted up as a showroom and the other floors are used as offices.

Norwall Mfg. Co., New York, has removed its office to 104 West 42d street, where it will be better able to show the Norwall vacuum systems of steam heating.

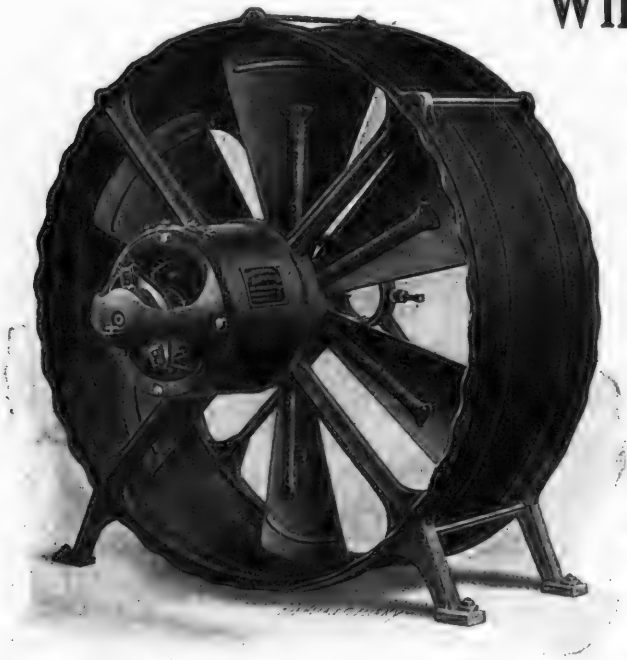
Black Carbon Coal Co., Spokane, Wash., are making arrangements to build a central heating plant to cost about $12,000. The ground purchased for this plant is 65x150 feet.

American Radiator Co., Pittsburg, Pa., has moved its office to 601-603 Hartje Building from the Farmers' Bank Building.

Thatcher Furnace Co., Newark, N. J., are enlarging their plant on St. Francis street, so that they may handle their increasing business. The building is to be 50x300 feet and equipped throughout with modern machinery, including new steam boilers and electric generating machinery.

Schaeffer & Budenberg Mfg. Co., Foxboro, Mass., has its new plant entirely completed. The firm has also opened an office at 225 Congress street, Boston.

Among the contributions for the San Francisco sufferers, made through organizations connected with the heating trade, are the following reported up to May 14: Manufacturers' and Dealers' Protective Association, $1,342.00; National Association of Master Plumbers (in addition to the lump sum of $1 000 voted by that body), $2,973.00. Many other individual contributions were made which will swell the total to a sum close to $6,000.



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WING'S Disc Fan and Combinations
WING'S Fans and Turbine Engines for Forced Draft, etc.
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WING'S Acetylene Generators, etc.

New Corporations

N. D. Phelps Co., Barre, Vt., has been incorporated with a capital of $25,000 to carry on a general mercantile, plumbing, heating and steam fitting business.

Frederick W. Ridgway Co., Albany, N. Y., has been incorporated with a capital of $5,000 to carry on a plumbing, heating and gas fitting business. The incorporators are: Frederick W. Ridgway, W. W. Branton and J. S. Gould.

Johnston Heating Co., New York, has been incorporated to manufacture hot water and hot air heating apparatus. Capital, $10,000. The incorporators are: William H. and Joseph F. Johnston and Thomas S. Harper, of New York.

The T. & V. Heating Co., Jersey City, N. J., has been incorporated with a capital of $100,000 to manufacture all kinds of heating apparatus. The incorporators are: J. L. George, J. H. Thissen and J. R. Vander Putten.

National Plumbing & Heating Co., Pittsburg, Pa., is the name of a nem firm, which is capitalized at $25,000. The officers are: William J. Bergens, president; George M. Hosack, vice-president; J. L. Stewart, secretary, and William S. Burchfield, treasurer.

Contracts Awarded

George G. Bodine, Bradford, Pa., heating the new plant of the northwestern Terra Cotta Company in Bradford. The contract also calls for a drying system to prepare the clay before its is placed in the kilns.

Standard Sanitary Mfg. Co., Pittsburg, Pa., installing a general power plant in the Standard Works, Allegheny. The plant will cost $100,000.

York Engineering Co., York, Pa., heating the Thirteenth Ward school building. The consideration is $6.350. Also heating and ventilating the new office building for the Pennsylvania Railroad Company at Baltimore, Md.

West Virginia Heating & Plumbing Co., Charleston, W. Va., heating the Hotel Frederick, Huntington, W. Va.

Newman & Cronin, New London, Conn., heating the new Mariners' Savings Bank Building.

Brunelle Co., Worcester, Mass., heating St. Mary's Church at Marlboro.

T. J. Mooney Co., Nashville, Tenn., plumbing and heating the new $100,000 building being built by Lebeck Brothers.

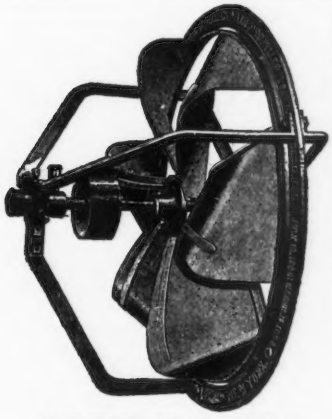
Chas. L. Anderson, Ishpeming, Mich., installing a steam heating plant for the new high school building at Norway, at his bid of $6,500. Also heating the new school building at Crystal Falls.

Murphy Heating Co., Detroit, Mich., heating the city hall.

Cleveland Steam Fitting & Supply Co., Cleveland, Ohio, installing the steam heating in the Oakwood Club House.

Lewis W. Butterfield, Orange, N. J., heating and ventilating the new Central School.

Fentzlaff Heating Co., Newark, N. J., gas-piping, plumbing and heating Pauline E. Thierlot's house and stable in South Orange. The consideration is $3,100.



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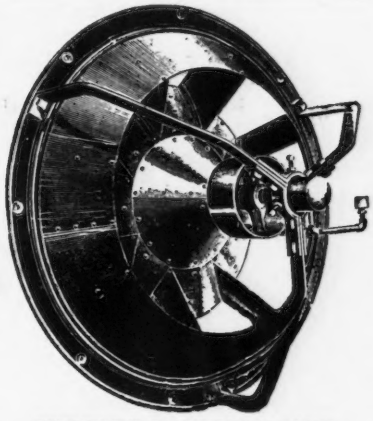
The Blackman and Duplex Cone Types



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MANUFACTURERS, ENGINEERS AND CONTRACTORS

Sprigg Bros., Grand Forks, N. D., plumbing and heating the First State Bank building at Lansford.

McGuire Bros., Rockford, Ill., heating and ventilating the High School at Monroe, Wis.

Peck-Williams Co., Cincinnati, Ohio, heating the First Intermediate School, Gest and Baymiller streets.

Darrow & Baker, Minneapolis, Minn., steam heating the Faulkner flats.

J. M. Dougherty, Ottawa, Ill., heating, gas fitting and plumbing the new city hall at La Salle.

Wilson & Wanless, Bay City, Mich., heating the new Lutheran Hospital.

America Heating Co., Rockford, Ill., has secured the sub-contract from Winchester & Cullen, for installing the heating system in the city hall.

A. Dussell & Son, Albion, Neb., heating the old school building. The contract is worth $2,845.

L. W. Dukerschein, Oshkosh, Wis., heating the Webster Manual Training School.

Campbell & Cowell, Valley City, N. D., installing the heating plants in John Holland's new residence and the Fifth Avenut Hotel.

Thomas Barwick Engineering Co., New York, heating and ventilating the Paterson High School, the Brooklyn Bath; also four pumping stations and the Red Cross Hospital, New York.

Sheehan & Groark, New Haven, Conn., heating the St. Louis Roman Catholic Church, Chapel street.

E. L. Lundwall, Bozeman, Mont., installing heating plants in the Irving and Hawthorne School buildings, at his bid of $6,000.

Elmira Ventilating & Heating Co., Elmira, N. Y., installing the heating in the Mill Street School at Poughkeepsie, N.Y.

H. Kelly & Co., Minneapolis, Minn., plumbing, heating and ventilating the new bacteriological laboratory at the State University, at their bid of $14,281.

Lewis & Kitchen, Kansas City, Mo., heating the new High School building at Ponce, Okla. The contract is worth $3,150.

C. B. Sherman & Co., Boone, Ia., heating and plumbing the new Y. M. C. A. building. Contract price, $2,611.

John F. Bealor Co., Pittsburg, Pa., remodeling the heating and ventilating systems in the county buildings.

Arnold-Evans Co., Spokane, Wash., heating the new armory.

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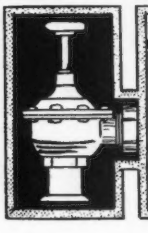

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the system of the future
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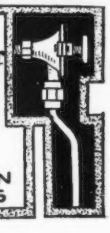

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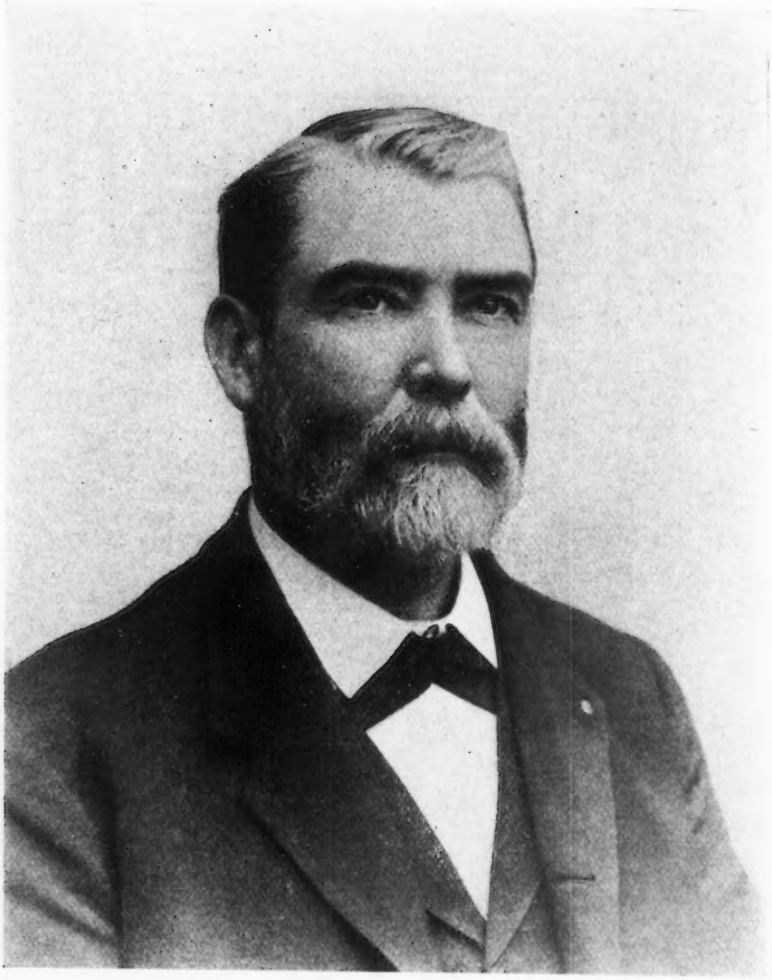
President of the National Association of Master Steam and Hot Water Fitters.